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WESTERN UNION Technical Review

Submerged Repeater

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Operation of Switching Systems

•

Patents

•

Testing and Regulating Overseas

•

Contact Materials

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CONTENTS

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Zo the Readers of he Technical Review

I appreciate the opportunity to write to you at this time. It gives me a chance to ›ress my best wishes for a Happy New Year to you and your families.

I also wish to express special and hearty thanks to the engineers, technicians and ›ervisors of Western Union, for whom this magazine is published, who have done a endid job in rapidly advancing the technical progress of the Company during my first › years as president.

So far as I know, no other communications company ever has faced so many stacles and, in spite of them, by hard work, perseverance and the wholehearted team rk of all departments, accomplished such a remarkable improvement in its efficiency operation in a period of a few years. The technical employees of our telegraph and ›le company have made substantial contributions to this progress. I am confident that y will keep us alert to take advantage of every opportunity for further progress.

In addition to the vast increase in our efficiency of operation, our mechanized :graph system now has twice its World War II capacity. We are better able to serve the ion in peace or war than at any time in the past.

This is a wonderful era. It is an age of high-speed electrical and electronic com- nication. With its technical experts, Western Union is out front and intends to › there!

Your knowledge and accomplishments are a source of pride and satisfaction to the nagement of Western Union. More power to you, and keep up the good work!

nuary 1, 1951

PRESIDENT.

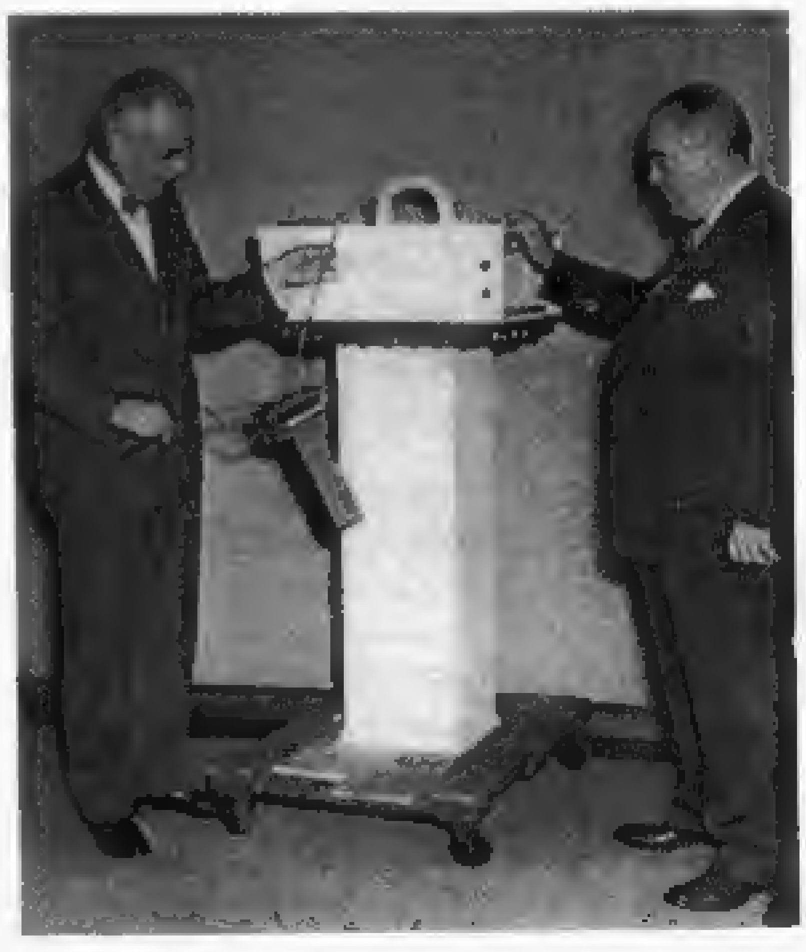
Submerged Repeater for Ocean Cables

F. B. BRAMHALL

News articles have told of Western Union's plans for the use of submerged repeaters to secure increased traffic-handling capacity on ocean cables. The first such repeater was placed in regular service early in October 1950 in a North Atlantic cable circuit which has shore station repeaters at Bay Roberts, Newfoundland, and Penzance, England. While as yet no fully descriptive technical paper covering the development has been released, this announcement of the success of the undertaking can be accompanied by a brief statement of the background of the work and an outline of the solution of the more difficult problems encountered.

The repeater under trial was designed for cables of the type commonly designated as the "old" cables, those which are not loaded and presently operate at speeds from 50 words per minute to about 100 words per minute. Encouragement for the development was offered by recognition of the fact that disturbances, both natural and man-made, which limit operating speeds on ocean cables are picked up almost wholly in shallow water near the shore ends. This being the case, it is possible to secure a very significant improvement in over-all signal-noise ratio by inserting an amplifier in reasonably shallow water just at the edge of the "continental shelf". Since the frequencies involved in telegraph cable signaling are at the bottom of the frequency spectrum, extending down to a fraction of a cycle per second, the components of such an amplifier are unfortunately of considerable weight and size. Contributing also to the weight and size are the shaping or equalizing networks required to suppress the very low frequencies so that the power-handling capacity of the amplifier may be a minimum. That capacity must be kept down because of the difficulty in supplying suitable heater and anode potentials over the cable for a distance of perhaps 200 miles from the shore end to the repeater location. The repeater includes a remote control switch by means of which the cable can be cut directly through and, incidentally, by means of which spare tube complements can be substituted in its various stages.

Technically the problems involved in this work have been mainly those entailed by the difficulties of securing a good hydraulic seal for the pressures prevalent under two or three hundred fathoms of water, plus those of actually installing the repeater at such depths. Building a 3-stage amplifier with the required 40 or 50 db of gain and the shaping network is



Vice-President in charge of Development and Research H. P. Corwith (right), and Transmission Research Engineer F. B. Bramhall (left), examine 1100-pound submerged cable repeater as they view a scale model showing how submarine conductor enters and leaves the unit

relatively simple. However, the problem of supplying heater and anode battery at a distance of 200 or 300 miles over a single-conductor cable having the attenuation of these old cables is not simple. Alternating-current battery supply cannot be used because of attenuation. Direct-current supply is difficult in the face of earth potentials which frequently run as high as a few hundred volts between cable terminals. The final solution was a d-c supply so regulated as always to deliver a fixed current to a ground at the repeater location. Actually the cost of the equipment required for this battery supply is perhaps as great as if not greater than the cost of the repeater itself.

The amplifier, with resistance-capacity coupling between stages, is transformer-coupled to the cable at the input and output terminals. It uses low-heater-current ruggedized long-life vacuum tubes which, with the remote control switch, are sealed at atmospheric pressure in heavy steel containers. The rest of the components in the repeater are at sea-bottom pressure in a bath of oil. The pressure within the housing is equalized to sea-bottom pressure by a sylphon bellows and piston arrangement. The sea-bottom pressure at the depth at which the installation was made is in the neighborhood of 700 pounds per square inch.

Western Union's plant includes a number of cables in which repeaters of this general type can be used to advantage. When more cables are equipped with repeaters reversible working will be provided; a westbound repeater will be cut in near the western shore terminal or an eastbound repeater cut in near the eastern shore terminal as dictated by the traffic requirements. The gain made in this initial installation is an increase from 50 words-per-minute working to 167 words-per-minute, which is accommodated by converting from single-channel printer terminal equipment to four-channel multiplex equipment. Through similar applications, on practically all of the unloaded cable network, a very substantial increase in Western Union's total cable plant capacity can be made.

First transatlantic cable repeater going under water

THE AUTHOR: Photograph and biography of Mr. F. B. Bramhall appeared in the October 1948 issue of TECHNICAL REVIEW.

Operations Engineering in the Development of Reperforator Switching Systems

DAN F. HAZEN

THE ENGINEERING of reperforator switching systems is customarily envisaged as embodying the development phases, such as the theoretical electric circuitry, laboratory proving, equipment designing, and plant construction planning. There is another concept of engineering which, while perhaps less dramatic in some of its applications, is nevertheless real and vital. This is "Operations" engineering. Some of the problems involved in operations engineering as they apply to the development of reperforator switching systems, and the relation that operations engineering holds to theoretical engineering will be discussed. Finally, the step by step operational planning for typical reperforator switching systems will be delineated.

Early Reperforator Installations

In so far as the domestic telegraph service is concerned, the idea of reperforator switching has unfolded through a process of natural evolution from Morse to teleprinter and multiplex to the reperforator method in a continuing effort to improve speed and efficiency. The first Western Union reperforator office was constructed as a pilot installation at Fort Worth, Texas. This office was converted from manual methods to an elementary form of reperforator switching in November 1934. Fort Worth served as the development prototype for the later systems of cord and plug reperforator switching. Cognate with Western Union development of switching systems was the Postal Telegraph Company's semi-automatic

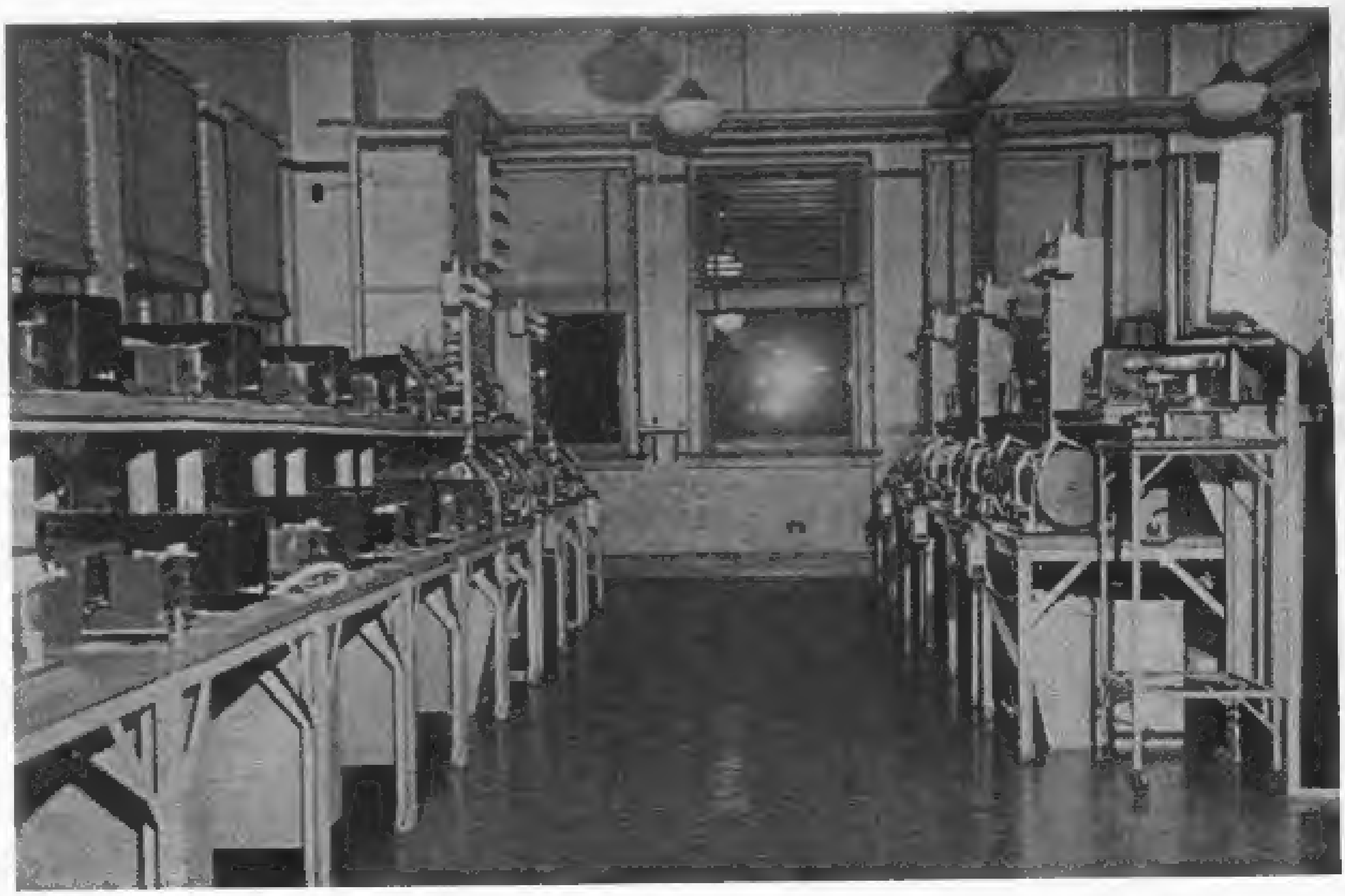


Figure 1—First Western Union reperforator installation—Ft. Worth, Texas

method. The first such Postal installation was the New York main office, which was converted in the spring of 1941. At the time of these early reperforator installations, traffic routing engineering changes were not a primary factor, and circuits which had existed in the replaced manual offices were largely continued in the new reperforator centers. These early reperforator offices, rather than being part of system-wide network outgrowth, were, in effect, simply a form of automatic replacement for existing manual methods in offices having large relay loads which permitted maximum economy in operation.

In this early development period, circuits between offices were established on the basis of load between principal cities within limits dictated by telegraph circuit capabilities. Facility capabilities placed definite limitations on circuit lengths, and the total number of available facilities was also limited. "Long haul" message traffic of necessity required a number of handlings or relays with resultant high operating cost and service perplexities. The practical advent of high quality Western Union carrier telegraph equipment in quantity opened a new avenue of approach to the over-all system routing problem. Reliable long distance telegraph circuits became a reality with a minimum required number of regulating points. Circuits were installed that were flexible, trouble free, and relatively inexpensive to operate. It is this system of carrier telegraph channels that has made possible the reperforator switching network as it is presently constituted.

Block State Routing

The present day concept of block state routing and reperforator areas was based on the termination of each tributary point within several state areas at a centrally located switching installation. The plan further provided that each reperforator center would have direct connections with the other centers and with certain large non-reperforator terminal centers such as Chicago and Cleveland and overseas relay gateways such as New York and San Francisco.

It would have been theoretically possible to develop one gigantic switching center with all Western Union offices having terminations in this center. Thus only one relaying operation would be required for the transit of a telegram between any two points in the system. Obviously such a scheme has many impracticable aspects. An absurd number of long distance circuits would be required for which economically full loads could not be expected. Complex and expensive circuit sharing equipment could possibly overcome this obstacle, but failure of one such large central switching point could conceivably disrupt all telegraph service. Aside from technical considerations, it becomes imprudent to concentrate beyond a certain point because of hazards of system disruption in the eventuality of storm damage, major power failure, atom bombing, and so forth.

Based on practical considerations, a long range development program evolved providing for the establishment of 15 reperforator switching centers. The planning provided for modernizing early models of reperforator switching plants or establishing new reperforator points at Richmond, Atlanta, St. Louis, Dallas, Oakland, Philadelphia, Cincinnati, Boston, Kansas City, Mo.; Minneapolis, Syracuse, Detroit, Los Angeles, New Orleans, and Portland, Ore. It was planned that at some future date certain other large cities having principally originating and terminating loads would be equipped with a modified terminal system of reperforator switching. The choice of locations for the centers was based on many factors, including proximity to facility centers or main circuit routes, nearness to theoretical and actual load centers, availability of operating personnel, sources of power, availability of suitable office and plant space, and others. The operations engineering considerations of determining the load center for a particular area will be analyzed later. It is an interesting observation that the Postal program for modernization called for the ultimate conversion to semi-automatic operation at 17 cities, most of which coincided with those cities chosen

for Western Union reperforator centers. The initial engineering planning of the two companies, however, was carried on entirely separately and without interchange of data.

Operating Routines for Reperforator Switching

It has been said that "operating routine picks up where the equipment engineering leaves off". Operating routine comprises the instructions and procedures necessary to produce an orderly, efficient, reliable, rapid, and safe movement of traffic. Basic operating tenets have developed over a long period of time. Changes in operating routine are made as a result of observations and studies to improve efficiency in operations. Other changes are necessitated to eliminate error or loss hazards which may occur with specific types of circuits. Throughout the evolution period of operating routines, certain fundamentals have remained unchanged. For example, a means of identifying messages must exist to facilitate tracing and service handling. Identification may consist of an arbitrarily assigned message or circuit number, or it may include parts of the message proper: i.e., the point of origin, date, filing time, address, skeleton, or any combination of these, depending on the volume and character of traffic being handled. A means of acknowledging received messages transmitted over electrical circuits is another fundamental necessity in the record communications service.

With the inauguration of reperforator methods, application of existing routines to fit the peculiarities of the new equipment and still provide the same basic safeguards and records became necessary. Those responsible for the development of operating instructions, and for the training of operating personnel in implementing the instructions, approached this problem by first making a detailed theoretical study of the equipment and circuit operation. Much of the applied engineering or physical layout of operating position equipment was done concurrently with the theoretical study by the operations engineers; thus an equipment layout was developed which pro-

Figure 3. Typical Postal Telegraph

vided a unit efficient for operational use since the applied engineers were able to take advantage of the operations engineers' skill in achieving operating room efficiency.

Semi-automatic or torn tape reperforator systems such as Postal's permitted operation under existing tested manual operating routines with few exceptions. Message numbering on outbound circuits was still a necessity but was accomplished automatically using a preperforated tape device. Record of receipt of messages by individual number sheet checkoff continued in a manner similar to that used in manual operation with an added function of recording subsequent routing on the number sheet to permit message tracing.

Western Union cord and plug, pushbutton, and the later selective switching offices, necessitated more drastic changes in operating routine. Some major problems were created by the separation of sending and receiving equipment in these offices into sending aisles and receiving or switching aisles. It became necessary to provide loud-speaker intra-office communication to facilitate application of the routine safeguards, opening and closing of circuits, and handling of wire outages. Supervisors' printer circuits were added to permit the direction of wires from tributary points into a central point within the office. Many fundamental routine requirements were, however, accomplished by automatic functions of the equipment.

To the greatest extent possible, tentative routines were completely developed for each new office to fit in with the characteristics and capabilities of the new equipment prior to actual construction work. This permitted early inauguration of operating personnel training, and simultaneously the new procedures were proven in and refined during the training periods of simulated traffic operation. Western Union reperforator supervisory personnel were required to have considerable knowledge of the relatively complex equipment and its operation; and the training period for supervisors required six or more months on a part time basis. In all cases the manual operating center continued in operation during the construction, testing, training and cutover phases of the new units.

Terminal Equipment and Trunk Circuit Studies

It is an operations engineering function to make such studies, on a continuing basis, as may be necessary to determine the types and quantities of terminal equipment needed for each terminal office whether it be reperforator or manual. From the fundamental equipment design factors such as speed of reperforator and transmitter operation, number of stations or offices which must share common equipment, and other related factors, theoretical sending and terminating message load capacities were determined for each of the several types of receiving and sending terminations available. This theoretical capacity was adjusted for operator production capacities at the various types of tributary and branch offices. Comprehensive message load and production studies showed the production capacity at offices having loads of such magnitude that one or more circuits are constantly in operation to be higher than that for a small office where operators spend a proportion of time on counter and other work. A capacity per channel for each given type of equipment was the end result of these determinations. The next step in arriving at type and quantity factors for a new center was the preparation of data sheets on every office in an area to be served by a new reperforator installation. Western Union operations engineers used data sheets which were arbitrarily called Reperforator Switching Data forms, or RSD forms, for this purpose. Complete representative load studies; present methods of operation, that is, teleprinter, tube messenger, etc.; tie-line and agency connections; office hours; special data regarding unusual load peaks; incidence of rush traffic; office force considerations; and space occupied, were detailed for each outside office within the new reperforator

At this juncture in the determination of types of terminal equipment to be assigned for each office, actual working knowledge of the office under consideration becomes vital. A particular office may show an average daily load of a few hundred messages but, because of a peculiar type of seasonal or recurring unusual business activity, may experience periods when several thousand messages daily are handled. Compromise assignments must be reached in these cases so as to provide equipment that will give adequate service at optimum cost.

Existing circuit availability was often a determining factor in equipment assignment. Where circuit facilities were limited, it was occasionally necessary to terminate smaller offices at an intermediate larger manual office for relay handling into the reperforator center. Agency offices were terminated in such intermediate offices since agency loads are customarily small.

The routing engineer made use of the

FIGURE 3—ABBREVIATED TERMINAL EQUIPMENT LIST AND KEY TO EQUIPMENT SHOWN IN FIGURE 4

NEW ORLEANS, LA., REPERFORATOR SWITCHING CENTER

	Total Positions	Equipment Key
Selective Switching Sending Rack Type 4812		
For sending to trunk, tributary, T&R, and book circuits	90	SA
For sending to special switching receiving turrets	12	SB
For spillover, spare, and fallback use	16	SC
Receiving Turret Switching Position		
For receiving from trunk and special switching circuits	58	RA
For spillover, spare, and fallback use	20	RB
Special for book switching use	3	RC
Automatic Switching Tabled Out Receiving Position Type 4930		
For tributary and branch circuits	42	RD
For fallback and spare use	8	RE
Concentrated Reperforator Sending Racks Type 111-B		
For tributary and branch circuits	63	SD
For spare and special book circuits	25	SE
Reperforator Sending Racks Type 111-B		
For tributary and branch circuits	7	SF
For tie-line switching circuits	4	SG
For local receiving position circuits	11	SH
For spillover, spare, and fallback use	10	SI
Concentrated (Line Finder) Selective Receiving Circuits		
For tributary and branch circuits	108	RF
For fallback and spare circuits	6	RG
Way Station Reperforator Sending Racks Type 5106	34	SJ
For fallback and spare circuits	4	SK
Automatic Switching Local Sending Tables Type 5020	12	LS
Local Receiving Tables Types 77-B and 345 (positions)	10	LR
RQ-BQ Automatic Switching Local Tables	1	RQ-BQ
Tie-Line Reperforator Switching Tables Type 346	4	Not shown
File T&R, and Supervisor Printer Tables Types 341-A and 137-A	7	M
Special T&R and Supervisor Circuit Reperforator Sending Rack Positions	5	M

RSD form information in compiling a trunk circuit requirements list. This process involved a determination of total traffic to and from each area tributary office and every other state in the system. Since each state in its entirety is handled by one reperforator office, it was possible to arrive at a theoretical number of channels from the new reperforator center to each other reperforator and major manual trunk office in the system. Here again, consideration had to be given to any peculiarities of load to a given area and the assignment of channels given appropriate allowances accordingly

Office Layout

The field RSD study preparation and subsequent joint analysis by plant and operations engineers resulted in basic equipment outlays such as that shown in Figure 3. The types of equipment listed have been discussed technically in previous articles. It will be noted that spare equipment of each major type was provided to allow a degree of flexibility in initial and ensuing circuit arrangement or assignment within the central office Operationally, spare or fallback equipment is necessary to terminate extra circuits at times of unusual load condi-

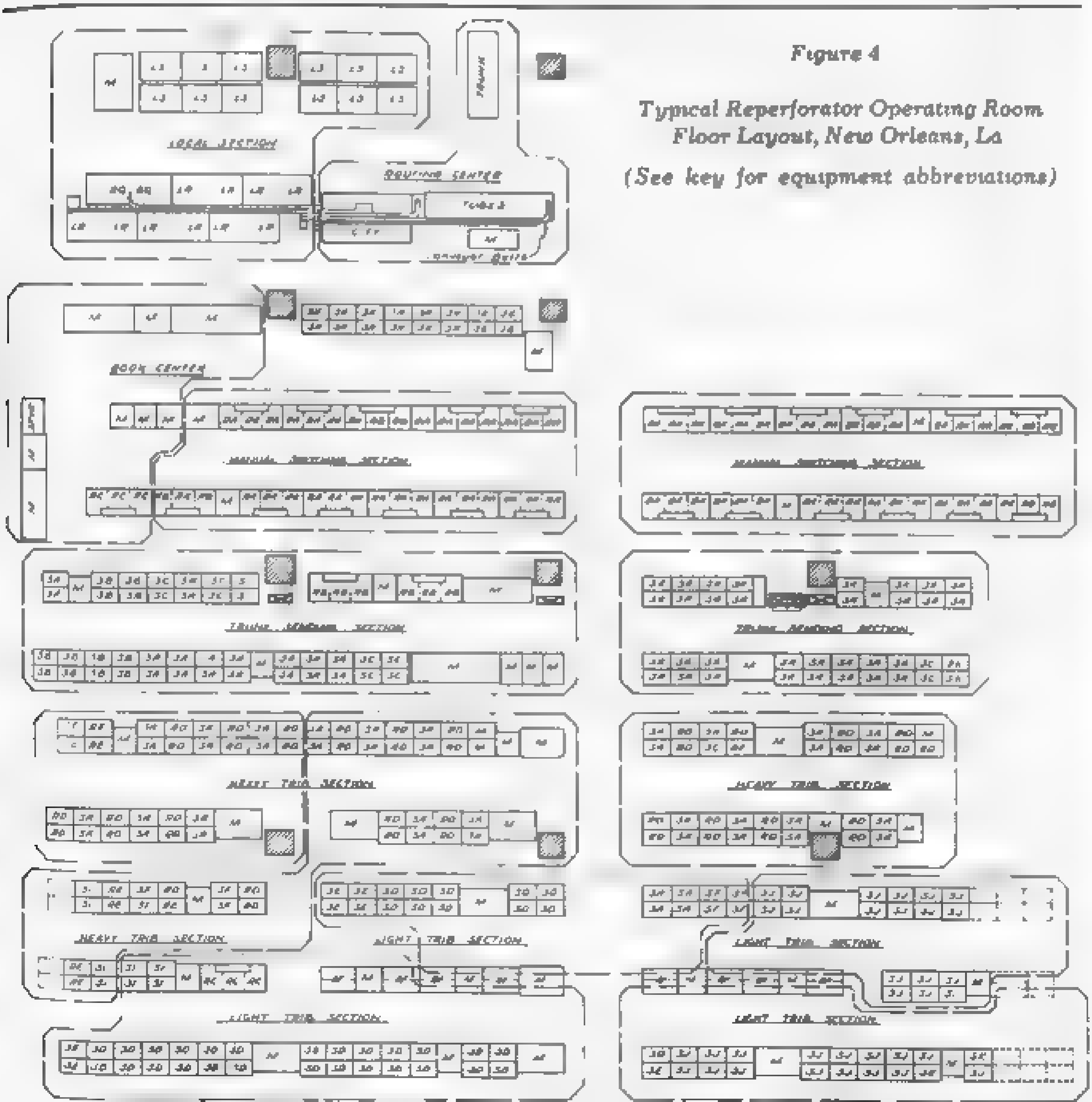


Figure 4

Typical Reperforator Operating Room Floor Layout, New Orleans, La

(See key for equipment abbreviations)

tions such as during featured sporting events and other activities where press coverage is heavy. Certain industries' files are frequently large enough for temporary periods to require such additional circuits.

Following the final determination of actual quantities and types of equipment needed, it became necessary to develop a floor layout which would provide optimum operating efficiency. A typical office layout is shown in Figure 4. Factors governing operations engineers' layout plan included balancing of supervisors' sections as to total number of offices and by total load terminated in the section, optimum travel distance for supervisors within the individual sending sections and within the switching aisles, optimum travel distance between sending section supervisory printers, optimum location of the central supervisor and her central routing and control boards, loud-speaker system coverage, accessibility of operating sections to entrance and fire exits, and the coordination of optimum operating layout with necessary changes in this ideal to accommodate the actual installation cabling ducts, lighting, and related equipment requirements.

Route Chart Revisions

During the office layout and assignment phase, the routing engineer progressed in the tremendous task of revising route charts for each and every relaying office in the system to show the major routing changes created by a new center as it was converted to handling whole states. Within the reperforator center, trunk and city routing charts were needed. Switching clerks required both types of chart since they were required to switch or direct properly all messages to outside office trunk and tributary circuits as well as to local branch offices serving definite zones within the reperforator city. Since large telegraph users were generally equipped with teleprinter or telefax tie-line equipment terminating in the central office, all such users necessitated listings on the city route charts by firm name, officials, building name, and street address, to permit a switching clerk to route traffic expeditiously regardless of the form of the message address. Development of city route charts was accomplished by personnel at the reperforator city who were already familiar with the local routing peculiarities. The route chart listings were duplicated on linedex strips to facilitate making the frequent changes in listings on all charts within an office as they occurred. Complete charts were required at each switching turret, at the supervisors' positions, in the local routing centers, and additional special routing charts were required at the local tie-lines section to cover detailed instructions for handling each tie-line user's message file.

Personnel Training

As previously mentioned, each employee who was to perform as a reperforator supervisor required up to six months of part time training in reperforator operation, assuming prerequisite qualification as an automatic supervisor. In addition, each operator who was to perform as a switching clerk received at least two weeks' training. Obviously the reperforator office operating employees were those already employed as operators and supervisors at the existing manual relay office, and they were trained on a part time basis so as to avoid disrupting normal manual office operation. Temporary diversion of existing load to other routes was a primary measure taken to facilitate the training. Use of alternate relay routes was thus implemented to divert a proportion of operator hours for training purposes. In many cases tributary circuits could readily be terminated in another relay office pending the completion of the conversion. A combination of these measures was used in each of the major conversion projects, thus permitting training requirements to be met with a minimum augmentation by temporary assignment of operating employees from other offices.

Training of supervisory and management personnel for a reperforator center was started almost as soon as the equipment installation. Traffic managers, assist-

ant traffic managers, and senior supervisors were detailed for several months to an existing reperforator center which provided suitable equipment and operational problems for management training purposes. The traffic manager in training was permitted to investigate all administrative and supervisory functions of the traffic manager at the training center and gain operating experience by actual job performance. While the time period for the training of management personnel varied, in most cases the "other office" portion was of several months' duration. As another training measure, the traffic manager at each new office was tied in closely with engineering plans as they were developed so he would have complete familiarity with the new plant. At their home offices, the traffic managers were given responsibility in connection with training their local office future reperforator supervisors and switching clerks.

Each operating employee in city branch, tributary, or distant trunk offices scheduled to work into a future reperforator center required training in the operating practices of the reperforator method. In many cases this requirement encompassed a number of operators in large central manual offices. One or more regular operating instructor or supervisor from each such office was given a thorough training course at a reperforator center so that he could properly instruct his home office operators and supervisors. Tributary office managers and operators were given two or more weeks' instruction and review at a central school. Where possible, each manager and operator was given a brief orientation at the new central office to broaden his understanding of his individual office's tie-in with the reperforator network

Cutover Planning

The Postal semi-automatic reperforator systems were all adapted to an "instantaneous" cutover, since the equipment design was such that circuit half tapping could be accomplished, and all circuit operation could be transferred simultaneously to the new equipment by a simple process of shifting message number sheets. Western Union systems involved more complex circuit and operating changes, however, and early cutover experience proved the value of a circuit by circuit conversion extending over a period of several weeks.

The actual cutover of a new center was preceded by preparation of detailed schedules covering operational and technical details of each individual circuit and channel to be converted. Definite responsibility was placed on individual technical employees and on operating supervisors for each detail of the changeover. Since load was removed gradually from the old manual centers to the reperforator switching center, a controlled means of handling interchanged traffic between the old and new systems was necessary. Temporary extra local sending and receiving positions filled this need. Temporary duplicate trunk circuits were provided for both the manual and the reperforator sections to give better control of office interchange load. As a part of the testing phase, each circuit was "dress rehearsal" tested by placing it in operation on its new equipment for a thorough working test prior to cutover

With the cooperation of the Western Union publicity director, the reperforator city superintendent made appropriate publicity and press arrangements prior to cutover, by conducting an invitation "open house" for large customers and stockholders, preparing publicity releases for newspapers and programs for radio stations in cities to be served by the new centers. Several days prior to each cutover, experienced supervisory and management personnel were brought to the new center and briefed in its peculiarities and on details of the impending cutover. Each was assigned some definite supervisory responsibility. Over-all control of the cutover was placed jointly in the hands of the traffic manager and an experienced representative from the general office headquarters. These individuals kept close watch on and regulated the progress of the cutover, acted as liaison with other reperforator centers,

Figure 5—Modern selective switching reperforator installation

and supervised operations generally Every possible safeguard to traffic movement was implemented to prevent confusion and loss of traffic during the conversions. During all of the later cutovers a "coordinating" desk was established in the reperforator center to provide a liaison point between the various groups of operating employees of the central and outside offices, the technical engineering and maintenance groups, and the supervising staff. This desk provided a means of rapidly correcting central or outside office equipment or line difficulties and operating routine problems. It provided a central point for preparation of cutover progress records and statistics and thus developed into the natural control center for the entire cutover

Following any initial operating period of new equipment, a reasonable length of time was projected for seasoning of new equipment and operators who naturally were somewhat timid and lacking in experience. As operator confidence was acquired through operation with live traffic, additional load was brought into each new system. Here again the operations routing engineer was able to accomplish much by implementing controlled changes in system routings and gradual discontinuance of the temporary diversionary routings made during the training phases. The prepared series of numbered routing guides was provided each major office throughout the country prior to each cutover. Each such chart provided for a change in the basic trunk routing As a new reperforator center called for additional load, appropriate routing charts were placed into effect system-wide by simple telegraphic notification to key offices

Initial cutover circuit assignments within each office were based on anticipated

cutover conditions of load, operator ability, and equipment performance. During the smoothing out post-cutover period the traffic manager began to make productive use of turret load studies, load distribution factors, sending load distribution, force assignment studies, and cost statistics. By means of channel patching equipment, circuits were relocated for optimum operational efficiency. Supervisory sections of responsibility were studied and adjusted. Quality control measures to maintain uniform and satisfactory speed of service through each part of the new centers were implemented. Monitorials were accelerated as necessary with increased load to maintain a satisfactorily low misroute performance by switching clerks. In those reperforator centers utilizing selective switching methods, quality control measures were instituted to monitor sendings from outside offices for accuracy and for proper use of selective routings. These measures, for the most part, were begun as continuing statistical studies during the early training stages. Force assignment and office control constitute a large percentage of any traffic manager's supervisory performance, and these factors are based on daily statistical studies and records of the types mentioned previously.

Conclusion

The Company is realizing a substantial reduction in operating costs as a result of the improved operating efficiency of reperforator switching methods. Over-all message handling capacity of the system has been doubled and, if circumstances should require, potentially the existing system can handle much more than its present capacity by making very minor equipment additions and changes. The reperforator switching network operationally provides numerous alternate routing possibilities for the reperforator cities. These alternate routing combinations provide a system well equipped to continue operations in event of an emergency which might isolate a part of the system. The Western Union reperforator system as it is now constituted is a noteworthy achievement in telegraph progress

The future of reperforator switching systems is promising. Research and Development engineers have progressed toward development of systems which will permit two or more successive circuit selections to occur. Plant and Engineering Department engineers continue to refine existing equipment and installations for more reliable system performance. Operations engineers are studying means of overcoming routing and other difficulties which create operational limitations. In time, application of such engineering may create a nation-wide network where manual attention is necessary only at the time of original typing and of reception at the ultimate destination office. In the meantime, Western Union operations engineers continue to investigate old and new approaches toward bettering production, accuracy, speed of service, and other operating efficiency factors

THE AUTHOR: Dan F Hazen, General Operating Practice Engineer, joined the former Traffic Department of Western Union as an apprentice engineer in 1940 following graduation from the University of Illinois. During the war he served in combat signal units of the armored forces and as Division Signal Officer of armored and infantry divisions On returning to the Company in 1946, he worked on maintenance and operating personnel training and traffic engineering for the Cincinnati and subsequent reperforator centers. Mr. Hazen is an associate of Sigma Xi and a member of Tau Beta Pi and Eta Kappa Nu honorary engineering societies. He is an associate member of AIEE.

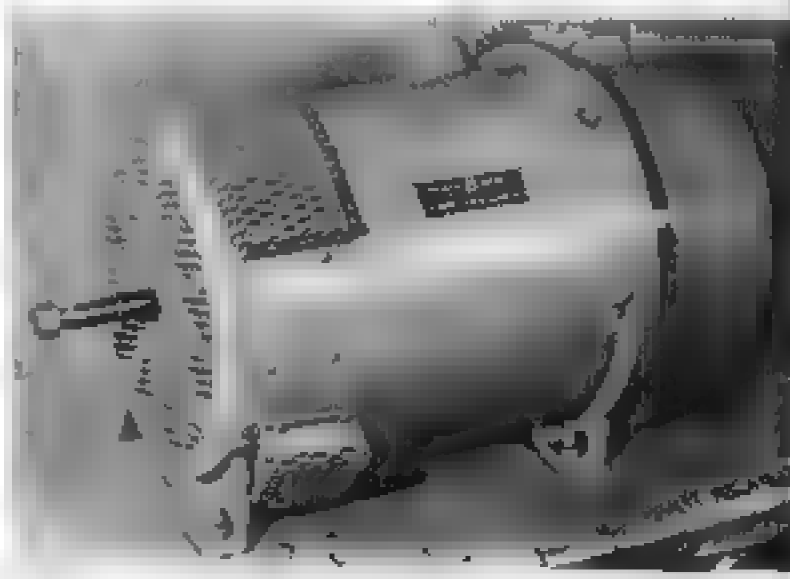
A Motor Alternator for Microwave Radio Relay Stations

PLANS for the expansion of Western Union's radio beam facilities have caused acceleration in the further development of emergency power equipment to meet the unusual demands of such a system. While the need for steady, uninterrupted electric power is fundamental to the operation of any telegraph plant, the conditions to be met at unattended radio beam relay stations are quite exacting. These stations are for the most part located on remote hilltops away from main roads with their substantial distribution lines, yet the communication circuits depending upon the station power may be greater in number than in most main telegraph offices. Thus while power plant installations at existing beam stations are giving good performance,[1] developments to improve the dependability of the power supplied are decidedly worth while.

The present relay stations utilize 60-cycle primary power for all needs, normally drawing this from a commercial power feeder. A storage battery floating on charging rectifiers, and a gasoline-engine-driven alternator stand by for emergencies. If primary power fails, the radio load is taken over almost instantaneously by vibrators operating from the storage battery while the engine is being started. When the alternator has been brought up to speed and voltage, the load is switched to this source. The primary power must be restored and remain for an appreciable length of time before the station is returned to normal conditions.

Although the relay-activated switching from one power source to another is done automatically and very quickly there yet is a momentary discontinuity in the flow of energy. The thermal inertia of cathode heaters in the radio equipment is sufficient to avoid trouble from this source but large capacitors are required on the d-c supplies to store a sufficient quantity of electricity to prevent momentary voltage fluctuations. Recent microwave developments have been in the direction of higher power requirements, indicating a need for still larger "carry-over" capacitors; in fact, there is even some doubt that vibrators powerful enough to carry the expected load can be obtained

An arrangement which appears to overcome most of the difficulties presented has been developed and will be tested shortly in the field. Briefly, the scheme is based on drawing power for the radio equipment at all times from a local alternator, which is driven by either of two motors in the same housing The machine, shown in the accompanying photographs, is supplied by the O'Keefe and Merritt Company of Los Angeles and will deliver two kilowatts. Utilizing a permanent mag-



Motor-alternator assembly, complete

net generator, an induction motor, and a shunt-wound d-c motor with retractable brushes, all on one shaft supported by ball bearings, the machine has no slip rings and since it will use the brushes only when necessary, wearing parts are reduced to a minimum.

In normal operation this machine is driven by the induction motor from primary power. Shifting to intermediate battery then to emergency engine-generator may be accomplished without opening the power circuit to the radio equipment. Preliminary tests have shown that the

rotor has sufficient inertia to maintain speed closely during switching operations, although fly wheels may be added to smooth out the power flow from the gasoline engine supply. Control of frequency and voltage regulation of the alternator over possible load ranges during the battery-driven period has offered some problems. These appear to have been overcome by the use of a motor field bias voltage supplied through a voltage stabilizer and rectifiers from the a-c output, further modified by several saturable reactors, one being frequency sensitive Adequate control is obtained over the range of useful battery conditions, from full charge to minimum voltage to carry the load.

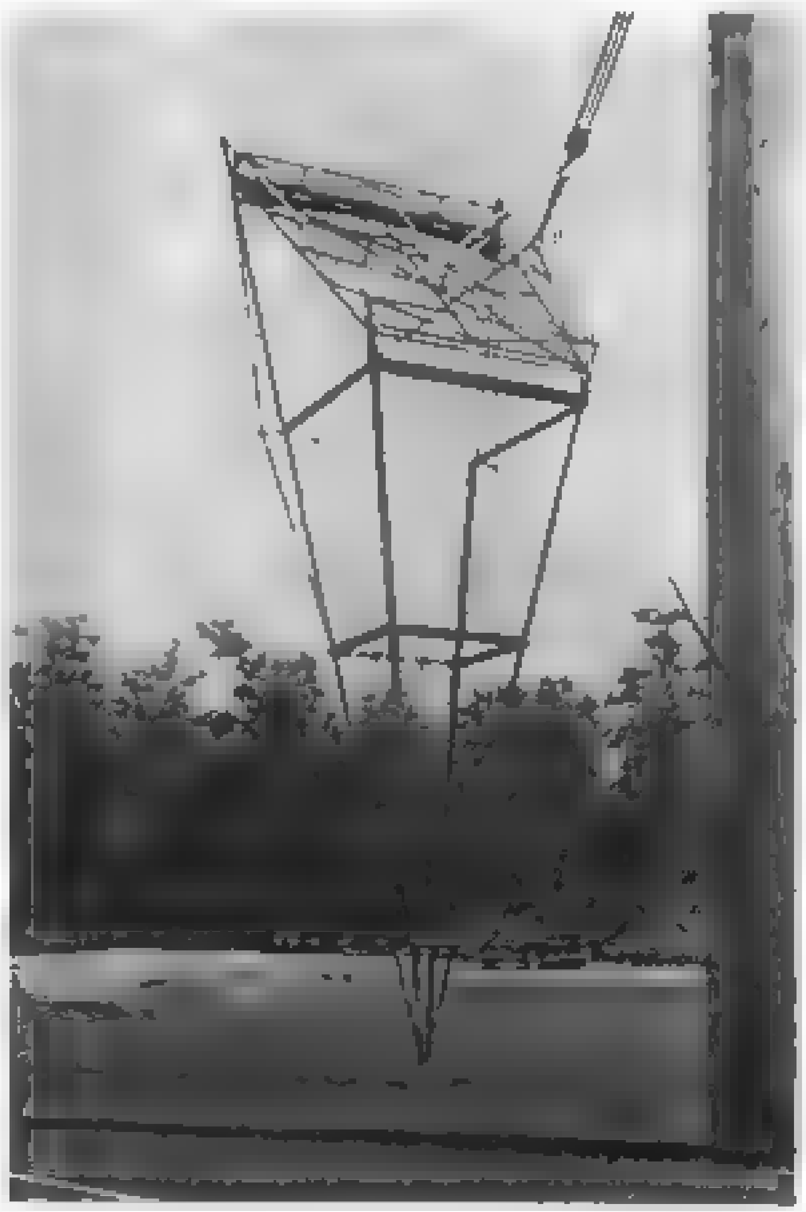
Motor-alternator shaft assembly; generator rotor with cooling fan in center

Reference

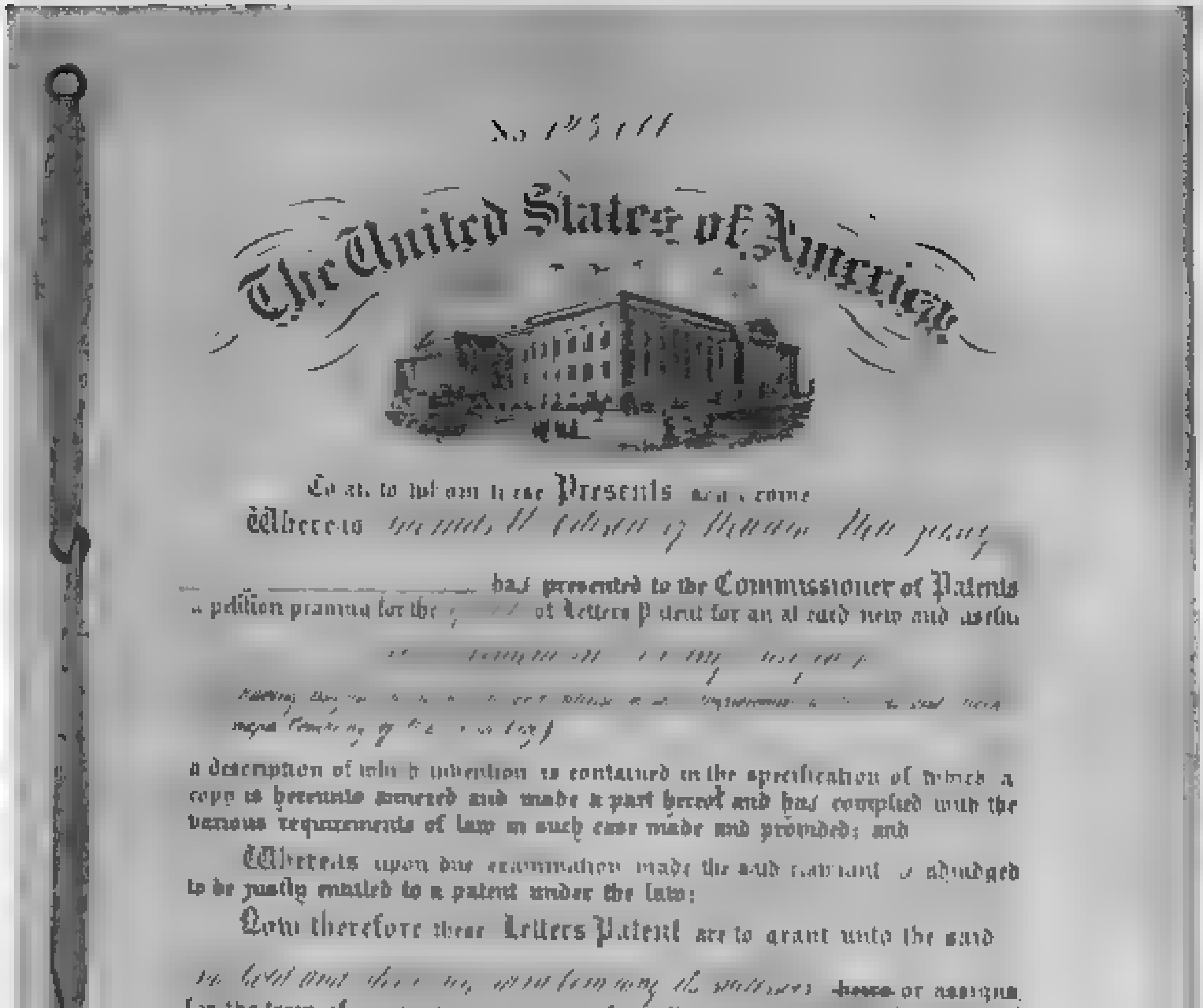
1. Power Supplies for Microwave Relay Systems H M WARD. *Western Union Technical Review*, Vol. 3, No. 4. October 1949. *AIEE TRANSACTIONS* Vol 68. 1949

An Experimental Horn-Reflector Antenna

Progress in the construction of an experimental horn-reflector antenna is shown in the accompanying photographs. The work, under the guidance of the Radio Research Division, is being done at Western Union's Water Mill Laboratories. This type of antenna is one of the possible solutions for the problem of achieving broadband energy propagation at microwave frequencies without the use of one antenna for each microwave channel



The two illustrations, one showing the assembled frame and the other showing fabrication of the reflector element, give some idea of the size of this experimental radio beam device The over-all height of the framework is approximately 20 feet. A technical paper covering the design and performance of this antenna will appear in a subsequent issue of Technical Review


The United States of America

To all to whom these Presents shall come:

Whereas

has presented to the Commissioner of Patents a petition praying for the grant of Letters Patent for an alleged new and useful

a description of which invention is contained in the specification of which a copy is hereunto annexed and made a part hereof, and has complied with the various requirements of law in such case made and provided; and

Whereas upon due examination made the said claimant is adjudged to be justly entitled to a patent under the law;

Now therefore these Letters Patent are to grant unto the said heirs or assigns for the term of years from the day of one thousand eight hundred and the exclusive right to make, use and vend the said invention throughout the United States and the Territories thereof.

In testimony whereof I have hereunto set my hand and caused the seal of the Patent Office to be affixed at the City of Washington, this day of in the year of our Lord one thousand eight hundred and of the Independence of the United States

Secretary of the Interior

Commissioner of Patents

Letters Patent granted in 1872 for the invention by Thomas A. Edison of an Improvement in Printing-Telegraphs

The Role of Patents in Western Union's Technical Developments

M. J. REYNOLDS

THE TECHNICAL ASPECTS of the Telegraph Company's engineering and research accomplishments, as they are unfolded in the TECHNICAL REVIEW and other scientific publications, tell a story of the ingenuity of its engineers and technicians in anticipating and solving the many problems in the development of a modern telegraph plant in a manner which will satisfy all of the complex traffic requirements prevailing in this industry. Prior telegraph practice and existing types of going plant impose certain limitations on freedom of design. The present day need for fast, efficient handling and routing of many different types of telegraph traffic prescribes other rigid requirements, and the need to look to the telegraph requirements of the future adds still further complications.

Just to make the problem more difficult there is still another angle confronting the development engineer which is often overlooked in evaluating his contribution to the industry. He must meet all the exacting engineering requirements and at the same time avoid the use of any expedients which form the subject matter of unexpired United States patents owned by outside interests and not licensed to Western Union. Obviously, it would be futile to design a system or equipment, however efficient and practical, if outstanding patents barred its use or required the payment to the holder of such patents of a tribute out of proportion to the advantages to be gained from such use.

The law assumes the research engineer to have knowledge of all of the six hundred thousand existing unexpired patents, and thus imposes upon him the duty of familiarizing himself with all patents which may be pertinent to his problem; having acquired this information, it is his further task to weave his way between or around such patents and to come up with a satisfactory solution that will conflict with none of them. And he must do this in the face of the fact that preceding inventors, or more specifically, their attorneys, have made it their business to enlarge the scope of these patents to the greatest possible extent, by prophecy or otherwise, for the specific purpose of forestalling any avoidance of them. The problem is particularly acute in the development of present day telegraph equipment because of the close relationship existing between modern telegraph techniques and those prevalent in the highly developed telephone, radio and electronic industries. The purpose of the present discourse is to indicate in a general way the part which patents play in the engineering developments of the Western Union Telegraph Company.

In general, all patents which are pertinent to a particular engineering development may be placed in three categories. (1) the expired patents (the helpers), (2) the unexpired patents held by others and based on inventions made prior to such development (the barriers); and (3) patents obtained by Western Union based upon the results of such developments (the protectors).

THE HELPER PATENTS

Expired patents are the development engineer's little helpers, and the word "little" is used advisedly. The life of a patent is 17 years from the date of grant, and upon expiration of that period the patent ceases to be a bar to the use of the invention covered by the patent. Expired patents are therefore sometimes a fruitful source of patent free expedients. Any system or equipment which is disclosed in an expired patent or which differs therefrom only in ways which would be evident to a skilled worker in

the art, is ordinarily available for use. There is a catch in this, however, which generally is not appreciated; there is always the possibility that the expired patent may be dominated by a broader patent still unexpired, the grant of which was delayed by extended proceedings in the Patent Office until after the grant of the expired patent.

The normal period between the filing of an application and the grant of the patent by the Patent Office is about three years, but in some cases this period is greatly prolonged. As an example, Patent No. 2,380,894 to Colman (not owned by Western Union), which relates to the storage and automatic switching of telegraph messages, was filed November 13, 1928, but did not issue until July 31, 1945. Consequently it will not expire until 1962, so that for practical purposes its period of influence on developments in this field is not 17 years but 34 years. Furthermore, any patent which is dominated by the Colman patent and which was filed after November 13, 1928, and granted before July 31, 1945 will not be freely available upon its expiration but only upon the expiration of the Colman patent in 1962. A long pending application, therefore, not only extends the period of domination of the invention covered thereby but often extends the effective period of related patents. Unfortunately, even in those cases in which the inventions disclosed in expired patents are free for use, more often than not they offer only limited assistance in the design of modern equipment since all expired patents are at least 20 years behind the times.

THE BARRIER PATENTS

It is a natural attribute of Western Union's engineers to desire to use the most advanced techniques, and therefore in any major development they are always confronted with a number of adversely held patents which have not expired. These patents are the barriers or hurdles which must be surmounted by one means or another, and this must be done without sacrificing economy in the manufacture, operation or maintenance of the equipment, or the efficiency or effectiveness thereof for its intended purpose. The procedures at the engineer's disposal for combatting such barrier patents are (1) to design his equipment in such a way that it will be free of the adverse patents; (2) to find means of restricting the apparent scope of the patents; or (3) to obtain rights to use the inventions of the patents.

Designing free of an adversely held patent situation requires close cooperation between the development engineer and the patent attorney. The logical sequence for the engineer is to survey the problem, draw up a general plan for its solution, and submit this plan to the patent attorney for a search and review of the pertinent patents relating thereto. Then in view of these patents the engineer must exercise his imaginative ability and ingenuity to modify the plan, if modification is required, so as to avoid the essential features of barrier patents while meeting all of the precise requirements of the proposed system or equipment. The engineer, if he is successful in devising such a modified plan, then proceeds with the more detailed development. This may require further patent study and further modifications to avoid additional patents which may be found. Such a step by step procedure is not always feasible, but whatever the method of approach it is the task of the patent attorney to search out the pertinent patents relating to the development and to interpret these patents for the engineer so that he may be properly guided in his efforts to avoid them. If this can be successfully accomplished, everybody is happy.

Too often for the engineer's peace of mind obstinate patents are encountered which defy avoidance, and at this point the patent attorney is again called into the fray. His task now is to find, if possible, a satisfactory way of restricting the effective scope of the claimed invention of the patent either because of a procedural defect in the grant of the patent or for lack of novelty in the subject matter. The search for procedural defects

involves a detailed study in the Patent Office of the history of the application upon which the patent was based, and includes such considerations as addition of new matter to the case during prosecution; inoperativeness or insufficiency of the disclosure; false or misleading statements which may have prompted the Patent Office examiner to grant the patent or any of the claims thereof; limitations placed upon the scope or meaning of expressions used in the patent which may have been made during prosecution of the application to distinguish the invention from previously issued patents or publications; and failure to comply with the various statutory requirements in obtaining the patent.

Searching for "Anticipation"

Lack of novelty simply means that the patentee was not in fact the first inventor of all or a part of the claimed invention, and the procedure for establishing lack of novelty or anticipation of the claims of the patent is to find one or more older patents or publications which disclose some or all of the features of the invention. This search must be conducted through both U. S. and foreign patent literature, and through text books, technical journals, and other scientific publications. It may also be necessary to ascertain whether any of the claimed features have been in public use in any previous systems or apparatus in this country and to obtain the evidence necessary to establish these facts.

When a pertinent publication or public use is found which is at least one year earlier than the date of the application upon which the barrier patent issued, this constitutes a statutory bar against the enforcement of those claims of the patent which cover anything disclosed in the publication or public use, and with respect to such features the patent may be disregarded. In a surprisingly large number of cases, earlier patents or publications are found which apparently did not come to the attention of the Patent Office examiner and which either restrict the scope of the patent or indicate that it would not be sustained, at least in its entirety, in a suit for infringement. Based upon the information obtained in such a search, the patent attorney must interpret the patent and advise the engineer which features thereof may safely be employed and which must be avoided.

Of course, the efforts to restrict the apparent scope of the patent are usually conducted concurrently with the engineer's efforts to design free of it, and in many cases the final solution is a combination of both efforts. The attorney, by cutting the scope of the patent down to its proper size, may enable the engineer to come up with a design which will avoid the patent. If these combined efforts fail, it may then be necessary as a last resort to negotiate with the patent owner for the purchase of the patent or for a license thereunder.

Licenses and Royalties

The acquirement of a license under such barrier patents could with equal justification have been specified above as the first resort. It is often more economical to pay a small royalty for the use of an invention than to employ a more expensive and sometimes less satisfactory means to avoid the patent. Western Union, with the view of giving the best possible communication service to the public, has adopted a policy of acquiring licenses under groups of adversely held patents in order to afford its engineers freedom of design and the right to employ the most modern methods. Such licenses may be royalty-free in return for a license back under Western Union patents, or they may require the payment of royalties to the patent owner.

An example of a royalty-free cross-license is one negotiated between Western Union and R.C.A. under which Western Union obtains rights in the field of wire telegraphy under R.C.A. patents, and in return grants a license under its patents to R.C.A. for radio telegraph communication. This license is supplemented by a further one which requires the payment of royalty by Western Union to R.C.A. for rights under the latter's patents in

the radio field including television transmission. Western Union has also been operating for some time under a cross-license arrangement with the Western Electric Company which includes rights on a royalty basis under Bell System patents in the important fields of telegraph switching, carrier current, submarine cable, facsimile, and others. By virtue of such licenses, numerous otherwise troublesome patents have been made available to Western Union engineers.

The effect of these licenses is to convert a large number of barrier patents into helper patents upon which the engineer may draw freely for any features disclosed therein which may be useful in the solution of his problems. This has eased to a considerable extent the burden on the engineer with respect to the design of infringement-free equipment, although it has not completely removed the problem since the patents included in the licensed groups constitute but a small proportion of those pertinent to telegraph technique. Moreover, the use of equipment which is free from patents on which royalties would have to be paid is still preferable where it involves no sacrifice of quality or service to the public.

THE PROTECTOR PATENTS

In addition to the expired patents and the adversely held patents, there is still a third type to be considered, namely, those based upon the developments of Western Union engineers. These are the protector patents. The advantages of acquiring patents on completed engineering developments are several-fold. They protect the large investment in engineering research by precluding others from appropriating the fruits of the research workers' labor without appropriate payment to Western Union therefor. They build up a trading position whereby Western Union is able to acquire licenses under patents owned by others in allied fields in return for licenses under Western Union patents, thus giving the engineers additional latitude in future developments. They also provide a substantial source of revenue in the form of royalties paid for the right to use the inventions of these patents, or of profits from the sale of equipment or supplies manufactured under such patents. In this regard it may be of interest to know that Western Union has sold more than 75 million square feet of its "Teledeltos" facsimile recording paper made under patents based on its research developments in this field.

Often the main purpose of a company in acquiring patents on technical achievements is to improve the competitive position of the patent owner by preserving to him the exclusive right to use the invention of the patent. In many advertisements of products there will be found an expression such as "This feature is exclusive with Bunco", or "Only Perfection can give you this." These statements are based on the assumption that the vendors' patents prevent the use of such features by competitors. Western Union, however, does not utilize its patents in this manner to restrict competition.

Patent Applications

An application for patent constitutes in patent parlance a "constructive" reduction to practice of the invention, and has the same legal effect in establishing a completion of the invention as would the actual construction and successful operation under service conditions of a full-size system or apparatus. It is therefore often advisable to file patent applications for the purpose of obtaining this constructive reduction to practice on improvements which have future potentialities but which do not justify immediate laboratory development.

The filing of an application for patent in some respects is similar to the recording of a deed in that it provides an incontrovertible record date in regard to the contents of the application, and is useful among other purposes in resolving controversies with inventors who may believe that they have suggested ideas which the Company is using in violation of their rights. The obtaining of patents also serves

as further protection by preventing subsequent inventors from obtaining nuisance patents covering any of the features of the patented development

Lastly, the issuance of a patent with the inventor's name on it encourages and stimulates the technician or engineer since he naturally takes justifiable pride in this recognition of his accomplishment, and it further enhances the prestige of both the inventor and the Company

While it has been stated herein that one of the duties of the attorney is to interpret patents for the engineer, the role is often reversed with the engineer explaining the technical aspects of the patent to the attorney. In fact, the patent attorney's effectiveness is determined in large measure by the assistance given to him by the technical men. It is only fitting, therefore, that this discourse should conclude with an expression of appreciation on the part of the patent attorneys for the assistance and cooperation so generously given to them by the technicians and engineers

THE AUTHOR: M J Reynolds, Assistant General Attorney in Charge of Patents joined Western Union in 1929 as a patent attorney and was instrumental in establishing the present Patent Department of the Company Previous to that he served as an Ensign in the Navy in World War I, was an Examiner in the United States Patent Office for five years, and for a similar period was employed as a patent attorney in the Lamp Division of the Westinghouse Electric & Manufacturing Company He was graduated from Rensselaer Polytechnic Institute in 1917 with a C E degree and from George Washington University in 1922 with an LLB degree Mr Reynolds is a member of the New York Patent Bar Association, the District of Columbia bar, and Theta Delta Chi

WESTERN UNION ELECTRONICS RESEARCH DIVISION IN ACTION

Work on a few of many diverse projects undertaken at the Company's Water Mill, L. I., Laboratories is shown here

Top left—wiring a Telefax transmitter

Center—microwave attenuator assembly

Top right—checking wiring of Desk-Fax chassis.

Lower left—spot-welding zirconium lamp elements.

Lower right—engraving a fork control bank face plate.

Testing and Regulating—Overseas

I. S. COGGESHALL

For the benefit of the many telegraph system T. & R. men who are readers of the Western Union Technical Review, the author will attempt to interpret the work of their associates who test and regulate the Atlantic cables. The task is simplified by the fact that a long history of end-on operation of land line and submarine cable sections to make up through, transoceanic circuits, has endowed the two branches of the art with common apparatus and a common vocabulary. A 21-A printer at the Horta station in the Azores is the same as one anywhere in the United States, and to adjust and overhaul it is the same task everywhere. That applies to distributors in St. Pierre, to the muxes in Havana, to start-stop printers in Antwerp, to the varioplex terminal racks in London, to the universal repeaters at New Glasgow, N. S., to the rotaries in Penzance, to channel repeaters in Montreal, to extended channels in Havre, and to the ubiquitous 17-B relay all over the world

Many of the common operations, like taking a balance, making a Varley loop test, sending "Jex" (or "Albert"), have the usual land line significance in cable practice, however differently they may be carried out in detail. Since London became a tributary of the Philadelphia reperforator for WUCABLES traffic, the T. & R. at Philadelphia has added itself to Washington and NPX New York in direct dealing with London T. & R.; and Western Union operators throughout the U.S. have become accustomed to receive London operators' good punching, and vice versa. Furthermore, because the Western Union Technical Review, containing cable as well as land line articles, is as avidly read by the T & R. abroad as in this country, both divisions already have more than a passing acquaintance with the problems and achievements of the integrated electrical system. However, there are interesting differences as well as points of similarity in comparing cables with land lines, and this article, for the sake of interest, will be focused upon the differences.

WUCABLES are anchored upon New York and Montreal as North American, and London and Paris as European, terminals, with extensions to Amsterdam, Antwerp, Brussels, Frankfurt, and Prague. At the Azores our cables are physically connected with Malaga and Rome through Italcable, and with Lisbon through the British system, Cable and Wireless. Through the same British system at Barbados we physically connect New York with South America; similarly at Havana we reach the Caribbean area. The land line system parallels the coastal cable feeders between New York and Nova Scotia—telephone v-f carrier to Bangor; open-wire line, partly transposed, to land line's universal repeaters at Fairville (St. John), N.B., and New Glasgow, N.S., and to the cable-land line rotaries at North Sydney. North Sydney also makes a wide reach across Canada by Canadian National carrier to Montreal in order that Montreal may work directly with London; a Montreal-New York multiplex completes the triangle. Land line carriers connect New York with Florida; at Miami and Key West, rotary repeaters serve to connect them with one cable to South America and three to the West Indies. In England we lease our underground physicals and v-f carriers from the British Post Office, and generally throughout Europe obtain land line and cross-Channel cable channels from the Governments concerned; but we are permitted to handle them with Western Union equipment and methods, as units in through circuits.

That brief recital, necessary to an understanding of the geographical aspects of cable T. & R. work, will serve the further purpose of showing that the Assistant Electricians, (as T. & R. men are called in cable practice), whether they be Frenchmen in Havre or St. Pierre, Eng-

lishmen in Penzance, Irishmen in Valentia, Newfoundlanders in Bay Roberts or Hearts Content, or Canadians in Canso, visualize their plant problems in global terms. To marked degree they are psychologically oriented along the line of their cables to the terminals, especially towards New York whence come equipment, procedures, traffic, money, and administration.

Typically, but with some exceptions, electricians at repeater stations are village folk, locally educated, trained on the job from late teens, holding what are considered good positions, usually occupying company-owned quarters, respected by townsfolk, and looking forward to retirement when eligible. Typically also, they work three shifts a day, rotate shifts monthly, and are glad when they can translate a 72-hour lay-over into a hunting or fishing trip. They like Sunday assignments and overtime when available, and, in general, react within the framework of their environment just as American T. & R. men would if in their place. Climate, of course, varies from the subtropical of Havana, Horta, and Penzance, to the fog of Nova Scotia and the snows of Newfoundland. Folkways and amateur sports supply the divertissements of a life essentially wholesome and leisurely in tempo outside the cable office. Within the office, though, if something goes wrong with a circuit or a piece of equipment just before market opening in Wall Street, these men respond as they would to a charge of buckshot—that is, in orderly fashion but with great acceleration, after the manner of good T. & R. men the world over

Transmission Speeds

Many of the differences between cable and land line techniques have their genesis in the transmission characteristics of the lines. Submarine cables were, of course, among the first coaxials, the energy in the wave front being propagated as an electromagnetic field in the gutta percha dielectric separating a central copper conductor from the surrounding sheath of iron armor, brass protective wrapping (if any), and sea water. In Table I are some round-number comparisons of the electrical transmission characteristics of (a) Open-wire No. 10 AWG copper pair, spaced 12 inches, with 40 pairs of glass per mile; (b) Submarine nonloaded cable, 650 lb. copper and 400 lb. gutta per nautical mile; and (c) Toll cable, nonloaded 19-gauge pairs. It will be observed that the resistance of submarine cable is kept at about half the wire-mile resistance of No. 10 copper, but that the capacitance in microfarads per mile is much greater for submarine cable than for either toll cable or open-wire lines. The resulting CR product of resistance and capacitance per mile for submarine cable is greater than for open-wire pair and less than for toll cable

In consequence, and ignoring inductance which influences but does not negate the result, if repeaters could be inserted with the same mileage between them in submarine cables as in open-wire lines or in toll cable, the maximum frequency transmissible would be less than for open-wire pairs but much greater than for underground or aerial cable. The nemesis of submarine cables has been that, at least up until the recent past, their great length in the oceans could not be sectionalized by insertion of repeaters.

Broadly speaking, and again ignoring, for simplification, a number of significant matters like noise-to-signal ratios, the maximum speed at which a cable or other transmission line can be worked is inversely proportional to its unit-length capacitance and resistance and to the square of its length. That is:

$$S = \frac{k}{CRl^2}$$

For a nonloaded transatlantic cable, l is 2000 miles between repeaters, and l^2 is 4,000,000. This is 64 times the value of l^2 when l is the usual 250-mile spacing between land line repeaters; the cable's speed is thus 1/64th of what its CR should give it if repeaters could be inserted as they are in open-wire line, say, between New York and Denver Table I shows how the formula works out for $l=50$, 250, and 2000 miles when $k=36$.

TABLE I

EFFECTS OF CAPACITANCE, RESISTANCE, AND CIRCUIT LENGTH ON SPEED

$S = \frac{k}{CRl^2}$		*Open-Wire Pair*	*Submarine Cable*	*Toll Cable Pair*
Capacitance (C), microfarads per mile		0087	4000	0609
Resistance (R), ohms per mile		6.7	1.8	83.6
CR per mile		.058	.720	5.091
	$l = 50$ miles	145	1800	12700
CRl^2, for	$l = 250$ miles	3625	45000	318000
	$l = 2000$ miles	232,000	2,880,000	20,360,000
"KR" $= CRl^2 \times 10^{-6}$		0.23	2.88	20.36
For $k = 36$ (see Note):				
	$l = 50$ miles	248,000	20,000	3,000
Speed in cycles per sec., where	$l = 250$ miles	10000.	800.	113.
	$l = 2000$ miles	155.	12.5	1.8

Note—When S is expressed in letters per minute and $k = S \times$ "KR", k has a value around 1728 for the 2000-mile nonloaded cable used in this illustration, and is often called the "speed constant." It is reduced to 36 by the relationship of 12.5 cycles per sec. to 600 letters per min. It will be understood that application of this equation to toll cable and open-wire line ignores inductance and interference and is therefore only broadly illustrative.

Terminal Equipment

When a nonloaded cable section is operated at 12.5 cycles or 25 fully-developed impulses, per second — and crowding the ceiling of its speed at that— it is evident that every expedient has to be adopted by engineers to derive full benefit from every pulse, and by T. & R. men to keep the circuit tuned up to a fine edge. One of the brilliant expedients adopted has been the use of a Gulstad vibrating relay circuit[1] working off auxiliary rings on the face plate to generate at the receiving point a double-frequency reversal which makes it possible to operate a 12.5-cycle cable at about 25 cycles. The 50-impulse per second signals transmitted are almost completely attenuated on the cable, are completely "shaped out" in the v-t signal-shaping networks in the receiving amplifier, and hence are masked by the locally created "singles"; the "doubles", at 12.5 cycles, get through, are amplified, and override the vibrating circuit "singles".

Even so, the cable is the transmission agency for but 25 cycles per second of intelligence. What can be done with it? Obviously, the carrier art has no place here. The multiplex, two channels at 50 words per channel-minute is the equally obvious answer. No room here for start-stop, or anything but the bare 5-unit essentials! Even if we wanted to, we could not abandon the mux on the cables.[2] However, with it we are quite happy. We can nicely fit a 12-subchannel varioplex on the 100 words a minute which the

two strapped channels afford. We can equip the ends with any desired kind of printer, or repeating gadget, or reperforator. Continuity being excellent, "hits" in the ocean bottom nil, shielding from atmospherics by a mile or two of salt water ideal, earth currents trapped by unshunted condensers or transformers at cable ends, local thunderstorms at northern cable stations rare—conditions could hardly be better for trouble-free operation

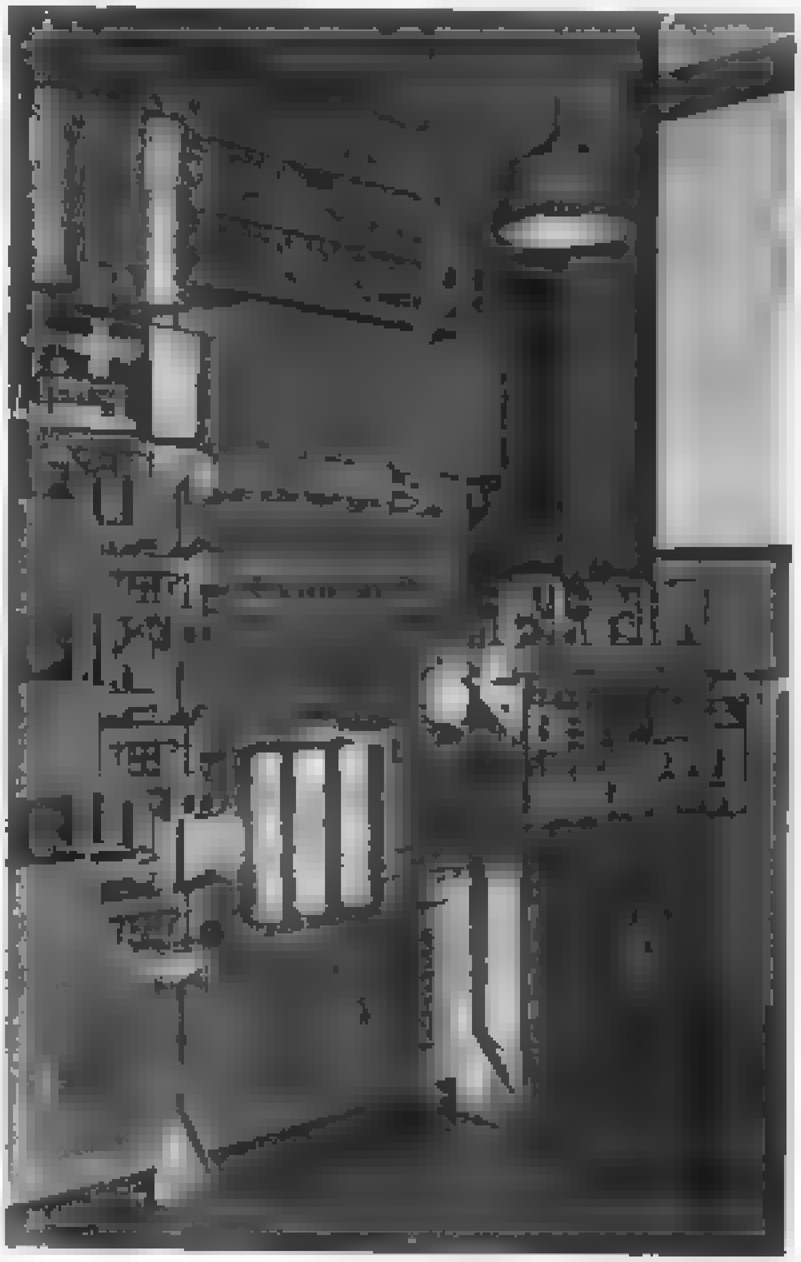


Figure 1 12-subchannel varioplex such as used at London

Transients

On a 250-mile section of land line worked at 25 cycles, where the velocity of wave-front propagation is about 178,000 miles per second, the front of the 0.0200-second impulse arrives at the next repeater and establishes steady-state closed electrical circuit conditions in about 0 0014 seconds. On a 2000-mile nonloaded cable worked at the same speed, the velocity is of the order of only 20,000 miles a second, so that in the tenth of a second that it takes for the first impulse to arrive at the distant shore, four more pulses may have started on their way. The concept of transients,[2] or a train of "spurts" chasing each other along the cable, is therefore a little different from that held by the average land line T. & R man. The difference is magnified by another distinction: in land line practice the main-line relay or distributor brush holds polarity to line steadily until it makes a sharp crossover to the opposite polarity as the relay armature moves or the brush touches the next segment; in cable transmission it is common to send into the cable through a large condenser which delivers a sharp "pip" to line on the transition space-to-mark and one of opposite polarity on the transition mark-to-space. The reason for doing so is, in part, to help shaping and to prevent zero-wander which would take place from the application of steady battery to line during successive pulses of the same polarity The cable electrician, therefore, looks upon the cable as a long elastic rubber hose, into which, with his condensers working like a piston, he can launch a sharp spurt of marking pressure in the form of a bulge that travels outward along the cable, growing attenuated and elongated as it progresses; followed in due course by an equally sharp manifestation of spacing suction in the form of a concavity that travels outward at the same speed, losing its depth and also elongating as it approaches the far shore

Cable Testing

In testing a faulty cable, the electrician comes up against its great length, sluggishness, and vagaries "in the raw", with battery applied under steady-state conditions, and no condensers or transformers to isolate the earth currents (or EC's), which are almost always present within the testing range of sensitivity. Instead of a deadbeat galvanometer on the Wheatstone bridge with which the land line T. & R. man makes a Varley, the cable electrician (ashore or aboard the repair

ship when cut in on the cable) appears with a table full of equipment embodying the most elaborate means of insulating all elements of the circuit from ground. The galvanometer, of the mirror reflecting type, "feels more ballistic than the most ballistic one ever issued in a physics class." The shades are drawn, the lamp lighted, and the reflected spot of light centered on the scale. The Varley connections are made, the distant station makes the required joining of the faulty cable with a good cable, the electrician adjusts his sensitivity, puts what he judges to be the proper number of ohms in the third leg of his bridge, and pushes the test key. The spot horizontally and majestically leaves the center, leaves the scale, leaves the wall and the one adjacent to it, and comes to rest somewhere inside the galvanometer. Try again!

Figure 2 Testing equipment aboard cable ship

After a few minutes of educated guessing, the electrician finally has the spot on the same wall as the scale. It sways back and forth as he moves the test key between its two poles. It continues to sway back and forth in response to the EC's when he leaves the test key alone. To his practiced eye it becomes apparent when his test key no longer modulates the EC's, and when the latter, integrated by the perception which results from experience, come to "rest" where he thinks false-zero should be on the scale.

This is one department where the land line man figuratively removes his hat. The interrupted portion of a cable consists of the resistance from shore to the break, plus the resistance at the break, the first obeys Ohm's law; so does the second—but with qualifications. R of the fault varies with different strengths of testing current and is different for negative than for positive battery. Some of the tests involve four values of testing current and a sheaf of calculations. For the fault is itself a tiny battery—made up of the exposed copper core, the iron sheathing wires, both immersed in the salt electrolyte of the sea. The resulting emf either adds or subtracts from the prevailing EC's.

Polarization, too, is present through electrolysis, positive tending to seal the fault, negative to improve the earthing. The exacting tests eliminate these spurious emf's and polarization variables from the equations. The home and distant stations make independent measurements, narrow the region of error to an ohm—in certain "overlap" tests, make the determination jointly. From cable splice-sheets, carefully made by the ship which laid the cable, and kept up-to-date after every repair, the ohmage is stepped off from the station to the fault, and converted to latitude and longitude. The electrical findings are usually more accurate than the navigation can be which puts the repair ship on the cable ground. Rarely does the fault come up in the grapnel,[3] but that is not because any care has been spared either by the station electrician or the ship's captain to check and double-check every record and calculation involved.

One type of cable "break" can be "repaired" by the shore-based electrician—and there he has the advantage over his brother wire chief. Pin faults in insulation are often sealed for weeks by

application of steady sealing battery of a few volts which releases a bubble of hydrogen at the core and maintains it there under pressures of several tons to the square inch. It is in the testing department of his work that the cable man strays furthest from land line doctrine and precedent.

Cable Balances

Cables are balanced for the same purpose as land lines, but because of the great length of the cable and the 10,000-to-1 ratio of outbound to inbound current values (in land line practice it is more like 3- or 4-to-1), the cable artificial lines are quite different indeed. The land line A.L. is contained in a small box with a few dials mounted on a table or panel in the instrument room; the cable A.L. consists of scores of sections, each variable; contains zero-temperature-coefficient units of capacitance and resistance; is enclosed in three to five large cabinets with thick walls and doors like a butcher's meat refrigerator; and weighs several tons. It is kept in a special A.L. room with constant, automatic control of temperature and with provision for controlling humidity. To obtain an entirely fresh balance may be the work of several days. Its performance under operating conditions is logged meticulously. Because the balance will vary as the noon-day sun warms the cable in shallow water on the beach, compensating adjustments are made from day to day, hour by hour, and from one season to another.

Modern balancing techniques[1] call for the insertion of networks in the artificial line to match the impedance of the cable due to inductance, as well as capacitance to ground, compensation for the a-c as well as the ordinary d-c resistance, and at all frequencies which analysis shows to be important to signal transmission; and resonant networks to reduce the unbalance in the higher signal frequencies and harmonics. Both string oscillographs and cathode-ray oscilloscopes[1] with retentive screens are used to watch and measure the progress of the balancing operation. The T. & R. men become adept in detecting and compensating for reflections caused by impedance discontinuities in the cable and A.L., and have a firsthand acquaintance of the effects, measured in milliseconds, of the progression of the wave front from home to distant terminal

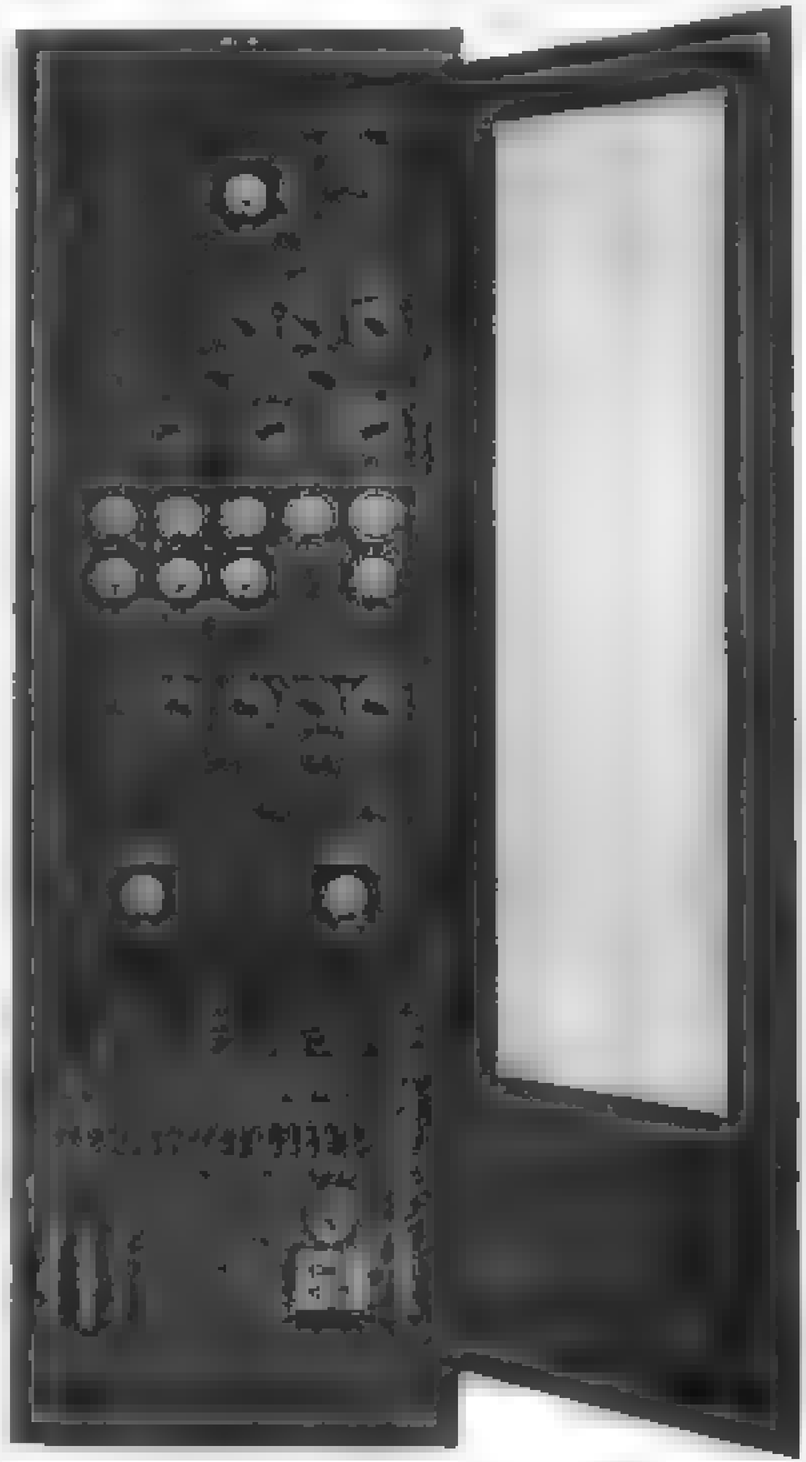


Figure 3. Ocean cable amplifier—front view

Amplifiers

Attenuation on an ocean cable at the very low signaling frequencies prevailing is of the order of 0.04 db per mile, or about half that on open wire carrying 10 kc. The 2000-mile multiplier again comes into play, however, and dictates a lift of from 80 to 100 db on cable amplifiers.[4] On loaded cables a 4-stage design has proven its worth since the mid-'20's; on nonloaded cables, a more modern 3-stage amplifier[1] is employed. Both types

TABLE II

Illustrative Deployment of North Atlantic Cables
Western Union Telegraph Company

Cable	*Dux or Spx*	*Eastward*	*WPM*	*Westward*	*WPM*
1 VA	Dux	New York—London	42	London—CO & NPX New York	42
				London—New York	42
2 VA	Dux	Montreal—London	42	London—CO & AP New York	42
				London—Montreal	42
3 VA	Spx	Spare	42	Paris—New York	50
4 VA	Dux	New York—Paris	42	Varioplex (Detail below)	50
				Varioplex (Detail below)	50
1 PZ	*Spx	New York—C & W London	50	C & W London—NewYork	50
2 PZ	Spx	Spare	50	London—Philadelphia	50
3 PZ	*Spx	New York—Paris	50	Amsterdam-London—New York	42
		Philadelphia—London	50	London—Philadelphia	42
4 PZ	Spx	CO & AP New York—London	50		
		Philadelphia—London	50		
		Varioplex (Detail below)	50		
		NPX & IMCO Nyk—London	50		
		New York—C & W London	50		
		New York—London	50		
		Varioplex (Detail below)	50		
		New York—London-Amsterdam	50		
1 HO	†Spx	New York—Horta	52	Horta—New York	52
		Utility Assignments	52	Utility Assignments	52
		Utility Assignments	52	Utility Assignments	52
		Utility Assignments	52	Utility Assignments	52
		Utility Assignments	52	Utility Assignments	52
2 HO	Dux	New York—Horta-Rome	52	Horta—New York	52
		New York—Horta—Lisbon	52		

Varioplex Details

On 4 PZ East 4 VA West		
	IMCO 1 New York—London	IMCO 1 London—New York
	IMCO 2	IMCO 2
	IMCO 3	IMCO 3
	IMCO 4	IMCO 4
	IMCO Bid	IMCO Bid
	W Washington—London	London—W Washington
	Utility Assignments	Utility Assignments
	Utility Assignments	Utility Assignments
	Utility Assignments	Utility Assignments
	Utility Assignments	Utility Assignments
	Utility Assignments	Utility Assignments
	WU T&R Talk Subchannel	WU T&R Subchannel

* Simplexed cables are reversible and are used East or West as needed
1VA, 2VA, 4VA may be shifted eastward also if required.

† 1HO is automatically turned around as often as once a minute

IMCO accommodates 30 or more pairs of customers on 4 subchannels of varioplex and 1 channel of 4PZ East.

NOTE Normal operation cannot be shown for obvious reasons.

incorporate shaping networks to compensate for a cable's discrimination against the higher frequency components of the signal, compared with the lower frequencies, of as much as 100 db. These amplifiers give trouble-free operation, as in land line practice. The cable T. & R. man watches tube life closely and tests the tubes frequently to prevent loss of emission while tubes are in circuit.

Simplex Working

A combination of circumstances causes a general traffic detachment of eastbound from westbound cable channels which land line people are often at a loss to understand. For one thing, cables are worked so close to their ceilings of capacity that, in order to make them up into workable units having speeds around 50 words a minute (300 lpm), it has been found advantageous to work with upset balances—two channels in one direction against one in the opposite. In Table II it will be observed that three of our ten transatlantic "VA" cables are so worked. Then there is the 8-channel loaded cable 4PZ which cannot be duplexed and whose traffic barrage is better left for long periods in one direction during the day than frequently turned around. Again, it has been found in practice that while a cable, in being stripped of its duplex harness and worked one-way, loses some of its total capacity, the loss can be turned into a gain if in direction E it is not needed, in direction W it is sorely needed, and if, by sacrificing all of E, W is increased both in traffic capacity and stability due to relief from all unbalance interference There is even clearer gain when, due to the great time differential between New York and London, the prevailing load peaks in the two directions do not coincide, and the cables can be "swung" to accommodate the prevailing peaks.

In land line practice, the T. & R. man becomes accustomed to seizing his circuits and channels in both directions in order to "go in" and accomplish his readjustments. In cable practice, the electrician lets his eastward side continue to run if only his westward side is in trouble. It is a matter of traffic spectrum again—the cable man has little he can set aside except for good reason. His "stops" come over a working channel rather than over a torn-down mux. The put-back, rerun, RQ-BQ practices naturally assume a different form under these circumstances, although every effort is made to keep cable and land line practices as closely as possible identical

Inspection of Table II will be of further interest to a domestic telegraph man. He will see that the whole Western Union transatlantic plant (10 cables) could be strung on one crossarm, and he may correctly surmise that there would be no transposition brackets used. He will count 30 one-way multiplex channels on the 10

THE AUTHOR: I S Coggeshall became interested in telegraphy as a wireless amateur and was licensed in 1911 He learned Morse operating with Postal in his home town of Newport, R. I., putting the knowledge to work by "scooping" while studying electrical engineering at Worcester Tech. Hired there in 1917 by Western Union. Mr Coggeshall, following an apprenticeship in the Boston office and war service in the Navy, served both the land line and cable organizations from 1920 to 1946, when the International Communications Department was formed and the author became General Traffic Manager He followed up his interest in radio through professional associations and is now president of the Institute of Radio Engineers, and chairman of the Telegraph Systems Committee of the American Institute of Electrical Engineers Mr Coggeshall represented Western Union on the Cable Committee of the Board of War Communication

cables, 22 of them going to the British Isles, 8 to the Azores. He will see several instances of one-way use of the familiar land line mux double, quite a few unfamiliar 1-channel muxes, a 5-channel mux, and an 8-channel mux. He will note that the channel speeds vary from 42 to 52 wpm, always at the capacity ceiling He will see no use of cable recorders on the North Atlantic route, everything having been converted to 5-unit printer operation. He will note with approval that the 5-channel cable turns out 260 wpm and the 8-channel 400 wpm, which isn't slow even between New York and San Francisco. He will surmise that the normal terminals of all facilities can be and are switched. He will find P Phila, W Washn, and NPX Nyk in their proper slots, and the varioplex broken down not only as to the mux channels which carry it but as to the 12 subchannels which the VPX affords. He will see how 4PZ East and 4VA West, those busy circuits, through five subchannels of the VPX, keep an additional 30 pairs of customers in New York and London happily interconnected through the services of a pair of switching operators.

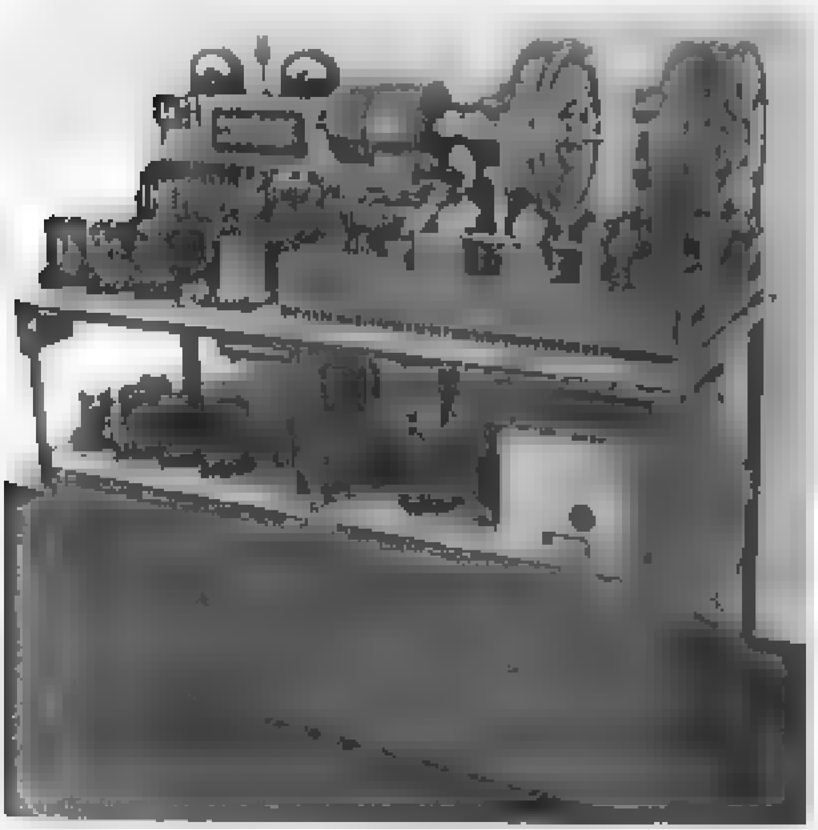


Figure 4. Five-channel distributor equipped to automatically reverse direction of transmission at chosen intervals depending on flow of traffic. Speed of cable 1625 lpm

Unfortunately neither the table nor this article, which has reached the limit of its length, can show the 25 one-way channels which Western Union projects on four cables into the Caribbean via Havana and into South America via Miami An account has already appeared in TECHNICAL REVIEW of the way we put two-channel-duplex FM carrier[4] on our Key West cables, as has another on the use of thyratrons[2] as regenerative elements in the repeaters at Bay Roberts and Penzance. A few cable and land line men could swap yarns about experiences in transmitting press photos over their respective facilities—it may be surmised that on a 2000-mile cable section, special arrangements had to be made[1]

Because the author entered the Company's service through the land line portal but has come to know the cable system through years of association, he takes particular pride in the achievements which have been wrought by hard work on both sides of the house, and particularly among the engineers, regulating men, and electricians whose work has had a common foundation in scientific progress. As they have shared the burdens of the past, let them share the vision of the cables' future as, today, the advent of the submerged repeater promises release from the ancient restraints of CRl^2. That future will be bright indeed if it sees our Company better serving the world community of trade and culture, our Government, and friendly nations overseas

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Contact Materials in Telegraph Apparatus

E. B. GEBERT and T. F. COFER

While a switch to turn electric current on and off in a lamp, motor, or household appliance is merely an adjunct to its operation, the sequence and timing of opening and closing circuits in telegraphy is basic to the communication of intelligence. Whether the contacting device be a telegraph key, relay armature, or commutator brush, the current in the controlled circuits must exactly follow its operation. For example, teleprinter sending cams control contacts which in each revolution of the shaft must make seven accurately spaced "opens" or "closes", each 0.022-second long, in the telegraph circuit. The receiving device samples a portion of each of the middle five intervals, on an elapsed time basis, to determine the character to be printed. The fidelity of the contacting function is therefore of paramount importance, since even momentary failure can alter or destroy the intelligence.

The search for contacts for telegraphic purposes which will perform correctly for indefinite periods has been in progress since the time of Morse, and has expanded from an electrical problem to include the results of research in metallurgy and mechanical engineering. Western Union has always been interested in obtaining the very best contacts for its apparatus and has therefore continued investigations in its own laboratories over the years to keep abreast of developments which have produced new and better contact materials and contact mounting techniques from time to time.

General Considerations of Contact Materials

As might be expected, the selection of contact materials for a specific exacting purpose is not a simple matter. Figure 1 gives in the form of a questionnaire[1] a list of the factors which influence such a project. The prospective user of the contacts would fill out Sections 1 through 6 inclusive. From this information the materials expert with a knowledge of the physical and electrical properties of the available materials can make a tentative selection from the list shown on Figure 2, subject to further compromises, if necessary. Lucky is the one who can use a sliding or wiping contact because these usually offer little difficulty in attainment. The butt contact is a more troublesome proposition and is, as it happens, the one most used in telegraphic apparatus.

All this seeming complication comes about because electrical contact operation is far from a simple process. Scientists in most of the industrial countries of the world have studied the process most minutely and yet have not reduced contact operation theory to an exact science. On one point, however, there is full agreement: that alternating currents are easier to break than direct currents. In the alternations between plus and minus current flow there must be a zero condition, at which point the a-c circuit may be broken relatively easily. Since so much of the difficult part of Western Union's contact studies involves direct-current circuits, this fact is of little assistance. However, from the several theories of direct-current butt-contact operation, a breakdown of the process into several parts may be made, starting with a closed circuit through the contact, as follows:

During the steady-state period, the contacts are closed with the full static force pushing them together, rated current is passing through the contacts and the voltage drop across them is due only to the volume resistance of the contact materials. In a properly designed device this should be a very small part of the total circuit voltage, since a sufficiently large amount of surface should be in contact to carry rated current without difficulty. But as the contacts open the last bit of material in contact melts. Probably due to the "Thomson effect", a physical phenomenon

related to thermocouple action, the positive contact is usually more heated than the negative, so it is material from the anode that forms a molten bridge as the contacts open further. The drop of melted material then breaks, thus transferring some metal from the positive to the negative contact. At this instant, if the voltage available across the contacts is more than contact surface. The heat from the arcing may be sufficient to oxidize the contact faces, which may cause difficulty on subsequent closings if the oxides are highly insulating.

If heavy currents are available, the arc stage may persist to fairly wide openings but in telegraph apparatus the current is usually much less than one ampere and

FIGURE 1—CONTACT MATERIAL SELECTION QUESTIONNAIRE

1.	Contacts for..				
2	Circuit	AC Normal Volts	Current	Contact } Open	Close
		DC Max Volts	Current	Duties }	Transfer
3	Type Load	Inductive Relay	Motor	Other.	
		Resistive Lamp	Other		
		Capacitive Line	Other..		
4.	Operation	Coil . Cam	Bimetal	Other	
		Frequency	Max. Travel Time	Max Spacing	
		Wipe, Slide or Butt preferable, explain			
5.	Forces	Static, closed.....	Impact		
		Available to open............			
		Tolerable bounce or chatter..			
6.	Ambient	Exposure Open	Detach Cover	Sealed	
		Atmosphere: Humid. ...	Salt	Dust	Oil or grease
		Gases or other contamination			
		Temperature: Max......................	Min.	Altitude	
7.	Tentative Design	Size and shape	Tolerance		
		Material and mounting...			
		Backing and assembly			
		Type spark killers necessary	Resistance		
			Capacitance		
			(Give diagram if necessary)		

the characteristic arc voltage of the material (12 to 17 volts) and sufficient current may be drawn from the circuit, an arc strikes between the hot spot on the positive contact and the slight protuberance of hot metal on the negative contact left at the breaking of the molten bridge. The arc may vaporize this excess material and deposit it over the positive the arc goes out at an opening of a few thousandths of an inch. Conditions existing in the contact area are still active, however, and a gaseous discharge associated with ionization of the gap may follow the extinction of the arc. If the voltage of the circuit being broken is high enough, sparking will now take place between the contacts. Because approxi-

mately 350 volts are needed to initiate such a spark and most telegraph circuit potentials are only 110 to 160 volts, this sparking does not occur from direct action of the circuit voltage but from the reaction of any inductance which may be included in the circuit being broken.

The magnetic field of a suddenly opened inductance will collapse at the rate necessary to produce whatever value of voltage may be needed to discharge the energy trapped in the magnetic field, breaking down the insulation between turns if no other path is available. Since in addition to the inductance there is usually some capacitance in the circuit due to the wiring, the sparking across the contacts ordinarily takes the form of damped oscillations, usually at radio frequencies.[2, 3] The action of a light spark on the contacts is to transfer material from the negative to the positive electrode. When the spark is violent, however, the material displaced by bombardment of spark ions may be blown out of the contact area. This sparking will cease, of course, as soon as the energy in the inductance is released and therefore is not of very long duration.

When contacts "make" the circuit, the conditions are not quite so complicated, especially if the closure is rapid as it must be for telegraphic purposes. The contacts may bounce or chatter, however, in which case a "make" can develop one or more very rapid "breaks" before steady-

FIGURE 2—COMMERCIAL CONTACT MATERIALS

A. Copper-base alloys
- Copper-nickel
- Copper-cadmium
- Copper-cadmium-cobalt
- *Copper-nickel-zinc (nickel silver)
- *Copper-beryllium-cobalt (beryllium copper)
- *Copper-tin-phosphorous (phosphor bronze)

B. Silver and silver-base alloys
- Fine silver
- *Silver-copper (coin & sterling silver)
- Silver-iron
- *Silver-zinc
- Silver-platinum
- Silver-palladium
- Silver-gold
- Silver-copper-nickel
- Silver-cadmium-nickel
- Silver-cadmium-copper-nickel
- Silver-nickel-copper-palladium

C. Noble metals
- Platinum
- *Palladium
- Gold
- Rhodium (electroplated)

D. Noble metal alloys
- *Platinum-iridium
- Platinum-palladium
- Platinum-ruthenium
- Palladium-silver
- Palladium-copper
- Palladium-ruthenium
- Palladium-silver-platinum
- Palladium-silver-copper
- Palladium-silver-nickel
- Palladium-silver-copper-nickel
- Gold-silver
- Gold-silver-nickel
- Gold-silver-platinum

E. Refractory metals
- *Tungsten
- Molybdenum

F. Materials made with powder-metallurgy
- Copper-graphite
- Silver-nickel
- Silver-graphite
- Silver-cadmium oxide
- Silver-lead oxide
- Tungsten-silver
- Tungsten-copper
- Molybdenum-silver
- Tungsten-carbide-silver
- Tungsten-carbide-copper
- *Tungsten-carbide-cobalt

*Materials frequently used in telegraph apparatus.

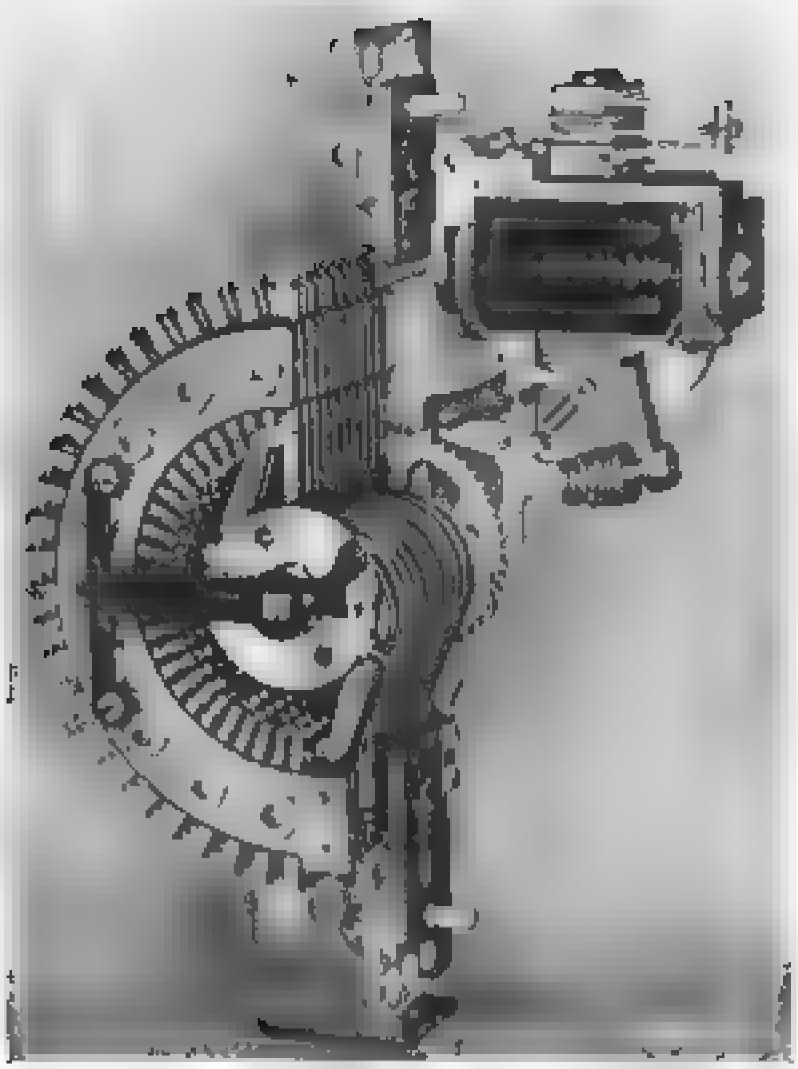

Figure 3—Rotary switch with phosphor-bronze contacts

state closure takes place. These breaks may not run the complete series of stages which follow a long closure but will contribute to some extent to the deterioration of the contacts.

It may be deduced from the above description of what happens when contacts make and break that butt-contact material should have good volume conductivity and low surface resistance in order not to load the circuit appreciably when closed; should have a high melting point and good thermal conductivity to minimize material transfer due to melting and arcing; should be chemically rather inert to reduce oxidation or the formation of film from other contaminants; yet should be mechanically strong to withstand the impact and pressures required to obtain rapid and certain contacting operation The search for the universal contact material has exhausted about all the suitable metals and gone well into the feasible metallic combinations, as may be seen from Figure 2. No single material offers all these properties to the desired degree, but for a given set of conditions several compromises may often be found Price, availability, and fabrication are practical features which have a bearing in many cases

Sliding or Wiping Contacts

Copper is the least expensive and most commonly used metal for carrying electric currents but because of its inherent softness and tendency to form non-conducting oxide films it is not suitable for butt-contact except for heavy duty applications. For sliding contacts, however, alloys of this metal are of great usefulness. The introduction of other metals as alloying agents imparts to copper increased hardness, resistance to arc formation, and reduction in erosion. The familiar tin and phosphorous alloy of copper known as phosphor bronze is widely used for commutator bars and brush springs on rotating contact equip-

Figure 4—Multiplex sending and receiving head with copper brushes

ment. In each Western Union reperforator office there are some half-million phosphor-bronze contacts on rotary switches (Figure 3) used for selecting circuit routings, operating with almost no trouble. Multiplex rotating equipment, Figure 4 once widely used for trunk telegraph service, operated satisfactorily for years with phosphor-bronze disc-commutators and woven copper wire brushes having a very light contact. Silver, used a great deal for contacts in other industries, is too soft for most telegraph purposes.

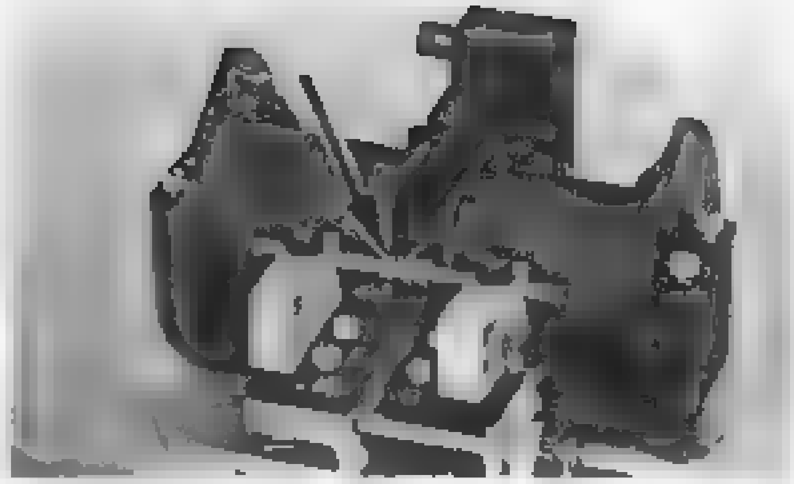

Figure 5—Western Union 17-B relay contact assembly

Butt Contacts

While fully sliding or wiping contacts have the advantages of being self-cleaning, with ample breaking space, good ventilation and cooling, and usually require for telegraph currents only light pressures even at high speeds of operation, the butt contact often has none of these attributes In telegraph relays such as the Western Union 17-B shown in Figure 5, the moving contact strikes alternately on the faces of each of the two stationary contacts at rates up to 140 contacts per second, the breaking space is only 0 006 inch, and the static pressure on the closed contact is 120 grams (4-1 4-ounces) under normal operating conditions. It is obvious that no soft material could tolerate the blows and the pressure without serious deformation, and a material with a low melting point could easily close the small gap with transferred metal

The noble metals, headed by platinum, approach the requirements for such contacts and for a number of years platinum-iridium contacts were used on 17-B relays with fair results. But platinum is peculiarly affected by small amounts of oil or grease, and even with the added hardening of the iridium alloy the contacts had to be cleaned and flattened once a day to maintain good service. These contacts were later replaced with a sintered mixture of tungsten-carbide and cobalt which completely eliminated the necessity for daily attention and is in use today on most of the 17-B relays in service.

A new relay of Western Union design, Figure 6, much smaller in size and somewhat superior in operation to the 17-B, utilizes the same sintered carbide contacts with static pressures of 250 grams (about 1,2 pound). These refractory metal contacts also appear in tape-operated transmitters, Figure 7, used in great numbers in the telegraph switching centers

By far the most concentrated array of butt contacts in Western Union today are those in the telemeter and the reperforator switching systems. Relays like those in Figure 8 in these systems utilize springs with contacts on their upper ends which may be controlled singly or in fairly large

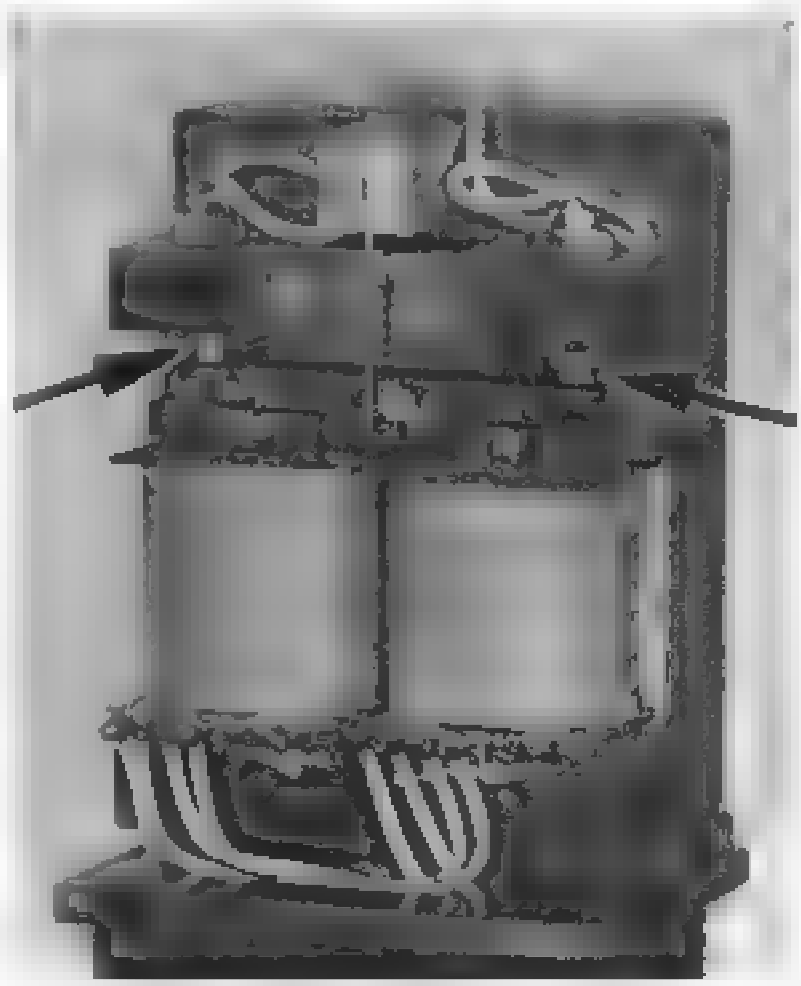

Figure 6—Model of new Western Union "bar" relay. Arrows point to contacts

groups by a single armature. On these relays, palladium has been found to give the desired service, successfully withstanding static pressures of 35 grams (1-1/4-ounces) and rates up to about 60 contacts a second. In the reperforator

Figure 7—Transmitter actuated by perforated tape

section alone of each of Western Union's 15 switching centers there are some 150,000 of these palladium contacts, operating to set up and hold circuits and to transmit the telegraph signals themselves. Some of these contacts must handle teleprinter signals at 125 words per minute or more in the cross-office circuits. Telemeter apparatus employs tens of thousands of the same kind of contacts, and the American District Telegraph Company, a Western Union affiliate, uses thousands more palladium contacts in their alarm systems equipment.

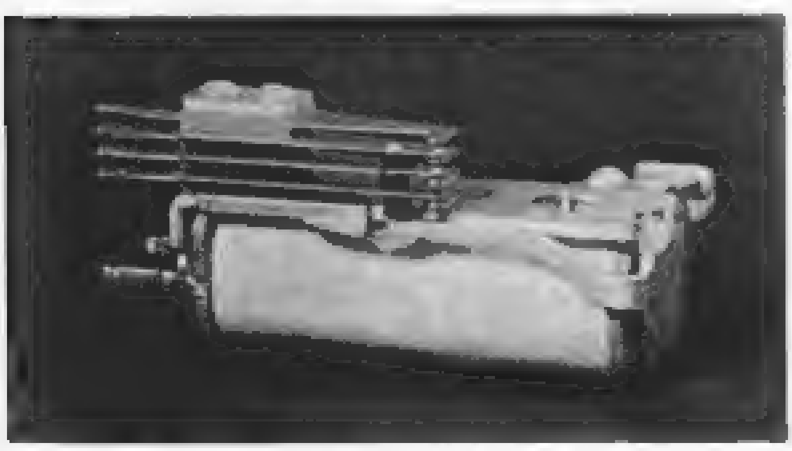

Figure 8—Spring-leaf relay with palladium contacts

While palladium contacts proved perfectly safe for ordinary telegraph currents up to one- or two-tenths of an ampere, certain of the heavy duty relays in the switching centers are equipped with platinum-iridium contacts to obtain longer life, at the expense of more rigorous maintenance requirements. The impulse units, Figure 9, each controlling a number of transmitters, are equipped with sintered carbide contacts where even platinum could not stand the erosion. In services like these, contacts must perform perfectly for several million operations.

Specialization Possibilities

Specialization of relays and other contacting devices in Western Union service cannot be carried out completely. The same kind of contacts may be called upon to work into different kinds of loads with different current and voltage requirements from time to time. Full advantage therefore cannot be taken of all the contact material attributes. Thus consideration

Figure 9—Contact assembly of transmitter impulse unit

has sometimes been given to the fact that the use of two different metals for a pair of contacts may be helpful in securing better operation. For example, material transfer between contacts, especially with inductive loads, can be minimized by using tungsten as the negative contact and silver-palladium (having a particularly low surface contact resistance) for the

positive contact. In telegraph operation it is usually impracticable to specify the polarization of contacts, hence such arrangements are of little value except in special experimental circuits. In other special cases the potentials developed by the galvanic action between metals may be of interest. In a special application in ocean cable service involving very minute currents, osmium was used as a contact material, proving very satisfactory for the purpose of minimizing galvanic currents.

Eliminating Bounce or Chatter

In almost all telegraphic applications contacts must be designed for fairly high frequencies of operation. The moving contact system must therefore be engineered to have a low moment-of-inertia to minimize the impact under the high accelerating forces necessary to provide fast action. It is also important that the contacts do not bounce or chatter, hence the momentum due to the developed velocity must be absorbed quickly or else overcome in some other way. The 17-B relays, having a very short contact travel, minimize bounce by the rate at which the operating force is building up at the striking time. At extremely high speeds, bad bounces still develop with this arrangement.

The most satisfactory method of absorbing the mechanical energy in a moving contact is through friction. In the new "bar" relay of Figure 6 the contacts have a slight scrubbing action as they meet so there is considerably less bounce at extreme speeds than with the older 17-B relay. The spring-leaf relays using palladium contacts also have a slight scrubbing action due to the spring arcs being slightly different and to the fact that the static contact is also on a spring and can ride with the moving contact after closure. Most of the cam operated contacts are supplied with backing springs which provide friction to the system in the same manner that automobile leaf springs, not lubricated, would do.

It might be noted, however, that where the mechanical energy is absorbed in the form of friction, the resulting heat must be disposed of within the contact system. At high frequencies of operation in poorly ventilated enclosures, especially with high ambient temperatures, this additional heat may be a factor in selecting refractory material for the contacts.

Contacts in Jacks

Most of the discussion of contacts has thus far been pointed toward the dynamic parts of the telegraph circuit, the switches and relays. Another important but somewhat less glamorous part of any telegraph circuit includes the contacts in jacks which permit attendants to cut in on the circuits for monitoring purposes or to change wire assignments. The contacts in jacks are usually between the brass sleeve and tip of the plug, which have to be kept clean and polished, and the springs in the jack. Auxiliary contacts may be made between jack springs.

The older Western Union jacks, designed primarily for heavy duty grounded telegraph service, used springs of copper-nickel-zinc alloy called "nickel silver",

Figure 10—Nine-conductor plug and jack

auxiliary contacts being made between serrated edges of the "normals" to the flat edges of their companion springs. Since nickel-silver has excellent resistance to atmospheric corrosion and may be obtained in a wide range of spring tempers, the material was eminently suited for the purpose. Its somewhat low electrical conductivity was offset by large cross-sections, and a tendency to form an insulating film under arcing was not serious

with the high voltages used on grounded telegraph circuits. As switchboards increased in size, a smaller jack was required and an arrangement of several assembled on a strip was found advantageous. These newer smaller jacks utilize phosphor bronze for both springs and auxiliary contacts, where used for direct-current telegraph purposes.

The advent of carrier current circuits, using comparatively small alternating currents, brought on the necessity for somewhat more positive jack connections than either of the above contact arrangements would provide. An alloy of silver and zinc, developed in the Western Union laboratories, was found to be the solution to this contact problem. Silver-zinc contacts will maintain low surface contact resistance for long periods of time while exposed to the atmosphere. Such contacts are, however, not very desirable on circuits of high current levels.

A most interesting type of jack and plug was used in the early type switching center. As may be seen from Figure 10, this combination switches nine circuits at one plugging operation. The contacts were made between eight phosphor-bronze rings and a button on the plug, to beryllium-copper springs, sometimes with phosphor-bronze shoes, in the jack. The wiping action of the jack and plug arrangement made the use of these contact materials possible.

Spark Killers

A discussion of contact materials would not be complete without mention of the important part played by spark killers. The destructive action of sparking and arcing at contacts, particularly those operating into inductive loads such as relay coils, has been touched upon in an earlier paragraph. Where continuous operation over long periods of time without attention is required, some kind of sparking protection is mandatory on all contacts subjected to such loads. The more complicated spark killers used in combination with devices to eliminate disturbance to

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T. F. Cofer's photograph and biography appeared in the October 1950 issue of TECHNICAL REVIEW.

Telecommunications Literature

Henceforth on occasion the REVIEW will call attention to new books in the field of communication. This feature is inaugurated primarily on behalf of Western Union maintenance and engineering personnel from whom requests are received frequently for recommendations on texts, reference works, and handbooks in the varied fields of communication technology. No special effort will be made to review or comment on all new books, hence omissions of even some outstanding works should be taken as meaning merely that appropriate evaluations have not come to the attention of the editors.

PRINCIPLES AND APPLICATIONS OF WAVE-GUIDE TRANSMISSION — GEORGE C. SOUTHWORTH—D. Van Nostrand Co., N. Y., 1950.

This book is written in such fashion that it will serve as an excellent handbook for microwave communication engineers, yet enough theory is given to satisfy those who wish to know the underlying principles. The excellent illustrations will make it informative also to those who do not work in this field. E. N. WRIGHT, Assistant Radio Research Engineer.

TELEVISION, Radio Corporation of America. Volumes V and VI, which are the eleventh and twelfth volumes of the RCA Technical Book Series, have been received. The papers are devoted exclusively to television and are presented under six major subjects: Pickup, Transmission, Reception, Color, UHF, and General. These volumes contain considerable information on the dot sequential system of color television, and the use of UHF for television broadcasting. Also, new tubes such as the vidicon and the 16-inch metal kinescope are described. The books are excellent reference material for anyone interested in the television art. W. B. SULLINGER, Radio Research Engineer.

(Continued from page 39)

radio reception have been well described in a previous article in the TECHNICAL REVIEW.[3] The very large number of contacts in Western Union switching centers which require sparking protection usually are not involved in radio disturbance production and hence can use a much simplified arrangement. Most of the contacts obtain ample protection from the action of a single small resistor shunted across the inductance associated with the contact. The value of this resistor is adjusted to the circuit constants and the applied voltage to reduce the transient open-circuit voltage to about 200 volts. In situations where the resistance required for this purpose would be of a value low enough seriously to slow down relay operation, a small condenser is added to absorb part of the inductive reaction, and a higher resistance is used.

Conclusion

Western Union operations are carried on today with far better contact performance than was experienced 20 years ago when there were many thousands fewer contacts in use in the telegraph plant. This improvement has not come about by chance but by the constant alertness of Western Union engineers in taking advantage of new and better contact materials as they have been made available through metallurgical developments.

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